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BULLETIN No. 156 OCTOBER, 1914

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ELECTRICAL INJURIES TO TREES

By GEORGE E. STONE

This bulletin deals with electrical injuries to trees, including a brief discussion of the electrical resistance in trees, as well as the effects of alternating and direct currents, lightning and earth discharges. The methods of preventing injury to trees from wires are also discussed.

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Approved by
The State Board of Publication.

ELECTRICAL INJURIES TO TREES.

GEORGE E. STONE.

INTRODUCTION.

In 1903 there was issued from this station a bulletin dealing with some new phases of the subject of electrical injury to trees.[1] This bulletin has been out of print for some time, and as many new observations — the result of years of careful study of the influence of electricity on plants — have been made, it has been thought wise to issue another edition. Many people are quite unfamiliar with certain types of injury from electricity occasionally to be found, and even those directly responsible often do not realize how serious the harm done is likely to prove.

The increase in electric railroads, electric lighting systems and telephone lines, whose wires are usually located near the tree belts of our cities and towns, has made necessary a lamentable amount of disfiguring pruning. When strung too close to trees, wires also often cause serious injury by burning, and sometimes mechanical injury is done; and even lightning discharges will cause harm when guy wires are attached to trees. (See Fig. 1, Plate I.)

Both the alternating and direct currents are used. They produce different physiological effects on plant life, the alternating current apparently being less injurious than the direct; and when either is used at a certain amperage it acts as a stimulus to the plant, and growth and development are accelerated.

There are minimum, optimum and maximum currents affecting plants. The minimum represents that strength of current which just perceptibly acts as a stimulus, and is a very insignificant current. The optimum is that producing the greatest stimulus — about .2 milliamperes — and the maximum, that causing death. (See Fig. 3.) Between the optimum and the maximum there is a strength of current that causes retardation in the plant activities, this being represented between R and MX in Fig. 3. The maximum current necessary to cause death is very variable. The direct current has a less stimulating effect than the alternating, and on account of its electrolyzing effect is capable of causing more injury to vegetable life than the alternating current.

Most of the injury to trees from trolley or electric light currents is local; *i.e.*, the injury takes place at or near the point of contact of the wire with the tree. This injury is done in wet weather when the tree is covered with a film of water, which provides favorable conditions for leakage, the current traversing the film of water on the tree to the ground. The result of contact of a wire with a limb under these conditions is a grounding of the current and burning of the limb due to "arcing." The vital layer and wood become injured at the point of contact, resulting in an ugly scar and sometimes the destruction of the limb or leader. In a large number of tests made by the aid of sensitive instruments with guy wire and other connections of wires to trees we have never found any leakage during fair weather, or when the surface of the tree is dry. Since the amount of current that can be passed through a tree depends upon the resistance and electromotive force, we shall consider this resistance at some length.

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[1] G. E. Stone, "Injuries to Shade Trees from Electricity," Bul. No. 91, Mass. (Hatch) Agr. Exp. Station, 1902.

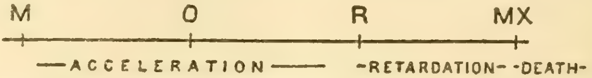

FIG. 3. — Diagram showing range of electric current affecting plants. M = minimum; O = optimum, or current producing greatest stimulus; MX = maximum, or death current; R to MX = retardation current.

ELECTRICAL RESISTANCE OF TREES.

The electrical resistance shown by trees is quite great, otherwise more injury might result from contact with live wires. The following table (I.) gives the electrical resistance of 10 feet of a maple and elm, each tree being about 2 feet in diameter and the electrodes 10 feet apart. These resistances were determined by a Western Electric Company combination bridge rheostat and galvanometer, and a large battery. Other resistances, however, have been obtained by means of the electro-motive force, and a known current passed through the tree, the two methods agreeing in their results quite closely. The table, which is taken from one of our previous publications,[1] is one of many.

TABLE I. — *Showing Average Electrical Resistance (in Ohms) of Maple (Acer saccharum Marsh) and Elm (Ulmus americana L.) covering a Period of nearly Three Months. Resistances taken on the North, South, East and West Sides of the Trees about Midday. Electrodes 10 Feet Apart.*

TREE.	Month.	East.	South.	West.	North.
Maple, ...	April, . .	18,550	18,185	20,500	20,800
	May, . . .	21,075	20,550	21,650	24,500
	June, . . .	19,775	19,761	21,883	22,550
Elm, ...	April, . .	24,300	26,075	25,700	24,275
	May, . . .	13,025	15,750	14,825	17,375
	June, . . .	14,992	18,608	17,508	17,883

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[1] Electrical Resistance of Trees, G. E. Stone and G. H. Chapman, 24th Ann. Rept. Mass. Agr. Exp. Station, 1912, Pt. I., p. 144.

It will be noted that these resistances were taken on the east, south, west and north sides of the trees, and represent averages of weekly observations. The lowest resistance (data not given in the table) obtained from the maple was 14,000 ohms, and the highest, 33.000 ohms. In the case of the elm the lowest resistance was 6,300 ohms, while the highest was 29,400 ohms. These resistances are relatively low, for in cold weather they often exceed 100,000 ohms. The lower resistance in all cases corresponds to periods of high temperatures, and the highest to periods of the lowest temperature. The difference shown by the various sides of the tree is also related to temperature.

As might be expected, there is considerable difference in the electrical resistance of various trees as well as of the different tissues found in trees. The heartwood, sapwood, cambium, bark and sieve tubes possess quite different properties and functions, and their electrical resistance would naturally vary to a large extent. The living cells containing protoplasm, such as are found in the cambium, present the least resistance, as shown by various observations on lightning discharges. The minute burned channel, caused by comparatively insignificant lightning discharges, follows down the cambium, indicating that this is the line of least resistance. Moreover, by driving electrodes into a tree to different depths and measuring the resistance it can be shown that the least resistance occurs in the region of the cambium.

The electrical resistance, however, may average throughout the year 25,000 ohms more or less in 10 feet of the trunk of a large maple tree. This constitutes a comparatively high resistance. The resistance of the sapwood is very much greater, and probably that of the heartwood is even higher than that of the sapwood.

In determining the electrical resistance it is necessary to know the path or course of the current, and the only manner in which the resistance of different tissues can be determined accurately is by isolating the tissues. By girdling a tree and scraping the trunk down to the solid wood we can get the resistance of the wood. Mr. G. H. Chapman found the resistance of a freshly cut rock maple stem, 1½ inches in diameter, to be 70,000 ohms with the bark on, but 150,000 ohms when the bark was removed. The electrodes were 1 foot apart. Some of our experiments indicate that next to the cambium the phloem has the least resistance, followed by the sapwood. The outer bark appears to offer the most resistance, but when wet the resistance may be somewhat decreased owing to the less resistant film of moisture on the bark. The resistance obtained from an elm tree in summer, with the electrodes 10 feet apart and in contact with the cambium, was 10,698 ohms, whereas when the electrodes were inserted into the middle of the cortex or phloem we obtained 11,300 ohms resistance. When driven ¼ inch into the wood the resistance was 98,700 ohms. The outer bark gave 198,800 ohms resistance, but when the electrodes were inserted slightly deeper into the bark we obtained 109,900 ohms. It must not be understood, however, that these readings gave the electrical resistance of 10 feet of the various tissues enumerated except in the case of the cambium, since if these tissues were isolated the resistance would be much greater in some cases. They show that there is much difference in the resistance of different tissues, but in all cases we obtained merely a resistance of the cambium, together with that of a part of the other tissues which the current had traversed from its various points of entrance to the cambium. It is quite evident from our observations on the resistance of trees that the cambium gives the least resistance, the phloem next, and it is not at all unlikely that in some trees there may be some variation in this respect.

The resistance given by small tree trunks and woody stems, even for small distances, is quite large. About 4 feet of a young pear tree, including the root system, with a maximum diameter of stem equal to 1 inch, gave a resistance of about 300,000 ohms, and the resistance given by a tobacco plant, in which the distance between the electrodes was only 14 inches, was much higher (110,000 ohms to 165,000 ohms) than that shown by most trees at corresponding temperatures.

The water and various salts in the living plant undoubtedly play a rôle in resistance, and it might be expected that the various plastic substances would influence resistance.

The cambium ring is very insignificant in size, and even on a large tree the total area is small. In all probability it is the protoplasm itself which offers the least resistance to the transmission of an electric current: and even if there were no continuity it would be necessary for the current to pass through a great many cell walls even for comparatively short distances on the trunk. In case the protoplasm was continuous or there existed continuity, the strands would be so very small that they would undoubtedly offer some resistance. Whatever conditions prevail, trees show relatively high electrical resistances, a feature which is no doubt of some biological importance as trees are often struck by lightning. The high resistance of trees, therefore, is undoubtedly a protection in case of lightning strokes, since often the heat developed is enough to do only slight injury. On the other hand, if trees possessed tissue with relatively small electrical resistance they would be much more subject to injuries from burning from lightning strokes, and would be more seriously affected by currents from high-tension wires. The electrical resistance of trees is so high that it is doubtful whether injury ever occurs to them from contact with low- or even high-tension wires except that produced by grounding when the bark is moist. Any escaping current from transmission lines that can be transmitted even through the least resistant tissue is likely to be insignificant.

Effects of Alternating Currents.

The alternating current systems employed for lighting purposes vary greatly in their potential. Cases of burning from alternating currents are more numerous than those from direct currents because trees are brought into more frequent contact with the wires, and owing to the higher potential more leakage is likely to occur. The high and low voltage lines may vary from 100 to 100,000 volts. The high-tension systems are invariably constructed across country, and are naturally not brought into very close proximity to shade trees. No injury to trees whatever occurs from the low voltage (110-volt) lines, but the lines of higher potential found on streets constitute a source of danger to trees. The higher the electrical potential the more dangerous the wires become to trees, for owing to the lessened effectiveness of the ordinary insulation, more leakage occurs and consequently greater opportunity for burning.

The effects of alternating currents on trees are local, producing injury only near the point of contact with the wire. Such contact results in death of that part of the tree, and if it is a leader or a large limb it usually has to be sacrificed. In no case, to our knowledge, has an alternating current caused the death of a tree, although it may burn or disfigure the tree so badly that it amounts to practically the same thing. It is doubtful whether the current from a fairly high potential wire would kill a large tree under any circumstances. It is different in the case of small plants, as has been frequently demonstrated in the laboratory, although the current must produce heat enough to kill the protoplasm. Owing to the close relationship between the maximum temperature required to kill a plant and that induced by electrical current, the collapse of the plant tissue in such cases is therefore due to the heat rather than to any specific electrical shock, as it is possible to pass the same current through larger plants where heat is not generated without causing any collapse of the tissue. The ordinary house circuit wires are perfectly harmless to trees, and it seems strange that a judge could render a verdict to the effect that an ordinary insulated 110-volt house circuit was responsible for the death of a tree whose terminal branches were located within 3 feet of it. This is the only court record of which we know where such a judgment has been given.

Very high-tension line wires are not provided with insulation and are known to affect the atmosphere surrounding them to a considerable extent. Any increase in the electrical potential of the atmosphere if not too high would favorably affect vegetation in general.[1]

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[1] There is evidently much difference in plants in this respect. A crop of radishes showed a gain of 57 per cent. when subjected to an average atmospheric potential of 167 volts, whereas an electrical potential equal to 500 or 1,000 volts is beyond the stimulation zone for some plants (16th Ann. Rept. Mass. Agr. Exp. Station (Hatch), 1904, p. 31).

It has been suggested that arc lights are injurious to trees, although we have never seen any cases of injury. It is well known that electric light is different from sunlight in its effects on plants, and it stimulates photosynthesis in proportion as it resembles sunlight in its rays. Some artificial lights contain rays that may act injuriously on small plants and in other ways modify their development, but even if a tree in close proximity to such a light should die it is no proof that it has been injured by this cause, as there are so many other causes for the death of trees.

EFFECTS OF DIRECT CURRENTS.

Most of the direct currents affecting trees are those used for operating electric railroads. Trolley feeders may be at 500 to 550 volts. Ordinarily the burning from direct currents is similar to that produced by the alternating current in being largely local or confined mainly to the point of contact with the wires. The feed wires cause no burning except when the tree is moist, in which case grounding takes place.

We have made a number of experiments, using large trees and small herbaceous plants, with direct currents from electric railroads showing the amount of current passing through trees, etc. In a number of instances a wire was passed from the tree to the rail or ground, and another wire was connected to a bare feed wire (450 to 500 volts) leading to some other portion of the tree, a milliammeter being placed in the circuit to obtain the actual current. The results were as follows: a young pear tree, 2 feet 8 inches in height, and 1¼ inches in diameter at the base, which had been growing one year in a box 14 by 16 by 9 inches, and provided with a copper plate in the bottom in direct contact with the roots, showed a current of 2.2 milliamperes (1/454 ampere) when one electrode leading to the rail was connected with the copper plate, and the other leading to the feed wire joined the top of the tree; 16½ feet of a maple tree 18 inches in diameter gave 25 milliamperes (1/40 ampere), and 7 feet of the same tree gave a current of 45 milliamperes (1/22 ampere). Connections made with a poison ivy (*Rhus toxicodendron* L.) plant growing on a tree showed in most cases similar results when the electrodes were inserted into the stem 2 inches apart. A stem ¾ inch in diameter gave a current equal to 4.4 milliamperes (1/227 ampere); ½ inch in diameter, 25 milliamperes (1/40 ampere); and another of the same size, 50 milliamperes (1/20 ampere). In the latter case, and some others not included here, the currents went down from 50 milliamperes to nothing almost instantly. From these experiments with ivy it appears that the current burned out the cambium or vital layer of the stem, leaving the dry and highly resistant wood which was unable to transmit a perceptible current.

In another experiment young sunflowers and tomato plants grown in 3-inch pots, with copper plates at the bottom, were treated from a direct current dynamo which generated an electro-motive force of about 60 volts. The plants were from 6 inches to 2½ feet high, and ⅛ to ¼ inch in diameter. When the current passed through 16 inches of the stem and copper plate to the bottom of the pot, a sunflower plant 3/16 inch in diameter gave scarcely perceptible readings; but when the current passed through only 1 inch of the stem and root to the copper plate at the bottom, the maximum current was 2/6 milliampere (1/384 ampere). This caused blackening and death of the tissues, perceptible a few hours afterwards about the points of insertion of the positive electrodes into the stem, and the plant was girdled for about two-thirds of its circumference. Very similar results were obtained with other sunflower plants treated in the same way. A plant 30 inches high and ¼ inch in diameter, subjected to a current of 10 milliamperes for some minutes, was not injured to any extent. In this case the current passed through about 1 inch of stem and ½ inch of soil. A young, succulent tomato plant, ⅛ inch in diameter and 5 inches high, was instantly killed when treated in the same manner with a current of 20 milliamperes, and a current of 2 and 3 milliamperes of 30 to 60 seconds duration accomplished the same result. In all the tomato plants considerable heat was developed. In one case in which an alternating current was used the plant lived for a number of days after the tissues had changed color and the plant had collapsed, as the vascular bundles or water-conducting tissues were not injured.

In the experiments cited all the injuries occurring were due to the effects of heat generated by the current. The experiments also showed that the strength of current which will kill one plant will produce not the slightest effect on another; in other words, the maximum current for each individual varies materially. Small, tender plants possess a maximum much below that of woody plants. The experiments were all carried on under normal moisture conditions; but when trees with a more or less thick bark are drenched with rain the conditions are quite different. A large maple tree which was in circuit with a feed wire (500 volts) and rail of an electric road gave a current equal to 70 milliamperes (1/14 ampere) with the electrodes placed vertically 1 foot apart. These connections were left on the tree for several months. The observations were made on dry days, and no heat developed with this current. During periods of wet weather considerable heat always developed, especially at the positive electrode, but not enough to melt the soft solder which connected the wires with the electrodes.

Examination of the tree ten months later showed that a portion of the tissues near the electrodes had been killed. After removing the dead bark an oval space 6 by 11 inches was found to be dead about the positive electrode and a space about 1½ by 3 inches near the negative electrode. The burned area about the positive electrode was about

95 per cent. greater than that occurring about the negative electrode. In each case it extended about twice as far above and below the point of contact as out to the sides of the electrodes, thus showing a tendency of the current to spread laterally as well as vertically, but more largely vertically.

The immediate area around the electrodes was more affected than that further remote. There was an area of tissue about 5 inches long between the large and small oval burning that was uninjured, showing that burning was confined about the electrodes. The current traversing the film of water on the bark between the electrodes was not sufficient to destroy all of these tissues at that point.

If a milliammeter had been placed in the circuit when the tree was wet a greatly increased current would have been detected, since the current in this case traversed the less resistant film of moisture on the bark. But the electrical resistance of the vital layer under such conditions would remain practically the same as when the tree was dry. The burning and injury in this case resulted from the heating of the film of moisture, which became so intensely heated that the vital tissue was destroyed, especially near the point of insertion of the electrodes. The more the film became heated the greater was the lessening of the resistance and increase of the current.

Practically all of the burning of trees from either alternating or direct currents occurs in this way, since the high electrical resistance characteristic of trees does not permit injurious currents to pass through their tissues.

Death of Trees from Direct Current.

Instances are known in which large trees have been killed by direct currents used in operating electric railroads. So far as we know attention was first called to these cases in Bulletin No. 91, issued by this station, but since the publication of this bulletin other cases have been observed in which the escaping current had burned and girdled the trunks for a distance of 5 to 10 feet from the base, the point of contact of the feed wire with the limb 18 or 20 feet above, showing little or none of the characteristic local burning effects usually observed in ordinary cases of grounding. In fact, the difference between the burning from direct currents in these cases and that from ordinary cases of electrical injury may be seen at a glance. On electric railroad systems the so-called positive current almost always traverses the overhead feed wire where the injury (burning) takes place. This differs only slightly from that produced by low-tension alternating current wires. In all cases of death from direct current electricity that have come to our notice the rail was positive, and the overhead feed wire was negative, constituting what is called a "reversed polarity." How common this practice is we cannot say, but apparently it has been done intentionally at times to prevent electrolysis as well as unintentionally by various companies, and is responsible in quite a few instances for the death of shade trees near electric railroads. There is much greater opportunity for extensive burning in the case of reversed polarity than in the regular systems employed. The moisture conditions of the soil and bark are such as to reduce the resistance, and in consequence the film of water and water-soaked bark become intensely heated, destroying the living tissues and girdling the tree to a considerable distance. The part of the trunk towards the rail is almost invariably the most severely affected. In the cases observed some years ago, where the current was reversed, there were no deep burning effects on the tree either above or below, — the rule when the overhead feed wire is positive (as is usually the case) and in direct contact with the tree. Moreover, the affected areas about the base of the tree are decidedly larger than when a positive overhead feed wire comes into contact with limbs. The entire area between the base of the tree and the overhead wire is not, as a rule, affected, although the extent of injury may vary somewhat. The injury from burning is confined to a space around the overhead wires, and also to the base of the tree. On the elm shown in Fig. 8, Plate IV., the burning was caused by a reversed system, and there was only slight injury at the point of contact with the overhead wire, while at the base about 6 or 7 feet of the tree was affected. This injury takes place when the soil and bark of the tree are moist, and may occur during a single period of excessive moisture, or intermittently. In some instances trees show serious effects a short time after the current has been reversed, when the bark will become loose and later fall off. The writer has observed both elms and maples — some of them 2 feet or more in diameter — which have been killed in this way. In some cases the trees were not more than 3 feet from the rails, while in others the distance was considerably greater.

In one well-planted city having extensive street railways, 51 trees were reported killed or so badly injured as to be of no value, 67 had large limbs removed, and many more were saved by removing limbs likely to come into contact with the wires. According to Mr. G. A. Cromie,[1] who had these under observation, the injured trees were in some cases located from 200 to 1,000 feet from the track. Some of the injury took place on streets having wires but no electric railways, and it is surmised that the ground connections were made through several pipe lines, located near the trees, which led very close to the electric railway. Mr. Cromie states that the effects on the trees were noted shortly after the street railway had changed its system, *i.e.,* using the rail to carry the positive, and the overhead wire the negative or return current. The trees in contact with the overhead wire became electrically charged, and when wet it was impossible for linemen to work on them. Under these conditions the insulation was much less efficient, and even wooden sleeves imbedded in coal tar and rubber proved of small use in preventing leakage, but otherwise there was little or no trouble from burning.

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[1] G. A. Cromie, "Scientific American" supplement, No. 1985, p. 40, Jan. 17, 1914.

We were able to examine only a few of these trees, most of them having been removed at the time of our observations; but a large percentage showed a characteristic burning at the base and the bark was burned off in some instances to quite an extent. One limb that had been in contact with the negative feed wire was found dead, but the tissue at the base of the trunk was normal. Dr. J. W. Toumey, director of the Yale Forestry School, who examined many of these trees, found a disintegration of the wire where it came into contact with the limbs, apparently due to electrolytic action, and chemical analysis showed the presence of copper and zinc in the tissues of the wood that had been in contact with the negative or overhead wire. Dr. Toumey believes that in such cases the disintegration of the copper wire and the absorption of the copper by the tissue were responsible for the death of the limbs. If true, this entirely new state of affairs would indicate that the electrical injury from direct currents not only arises from heat but also from the electrical disintegration of metals, which may poison the tissues. These observations demonstrate that we have a variety of conditions to deal with in considering the effect of direct current electricity on trees, and these phenomena may be summarized as follows: —

Burning and injury to plant tissue are much more noticeable at points with a positive potential[1] than at points with a negative potential.

When the rail is at a positive potential the overhead wire, which touches some part of the tree, is negative, and the bark and soil are saturated with moisture, and a circuit is formed by means of this surface moisture.

The moisture conditions and the electrical resistance, etc., at the base of the tree are different from those above, therefore a larger area of tissue is affected by the positively charged rail.

As the bark becomes heated through the film of water, the electrical resistance is reduced and the current increased to such an extent that the vital layer is destroyed.

The actual current passing through the inner tissues must necessarily be insignificant, and when there is a film of water on the bark, probably no current passes through the cambium; furthermore, the moist soil between the rail and the trunk of the tree becomes a better conductor for the current than the roots. The actual injury, therefore, is done by the current traversing the film of water rather than any of the inner tissues. The maximum heat and the areas most affected are near the base of the trunk.

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[1] Positive electro-static charges have a more stimulating effect on plants than negative charges, and retardation of growth and injury to the cells are more pronounced. The phenomena associated with the positive and negative galvanotropic bendings of roots may be explained in this way (24th Ann. Rept. Mass. Agr. Exp. Station, Pt. I., p. 144, 1912).

In regard to the possibility of injury to large trees by direct currents passing directly through them, experiments show that what holds true for alternating currents is true also to a great extent of direct currents. However, it would require a voltage much higher than that furnished by most electric railways at the present time.

It might be possible for direct currents to produce a weakening effect on the vital activities of the tree, although not causing any perceptible burning. If, for example, a tree was subjected to a strength of current equivalent to that represented between R and MX in Fig. 3, page 2 (retardation current), there might occur a disintegration of the cell contents, causing the tissues to become abnormal and finally die, but the electrical resistance of trees is so great that a quite high potential would be necessary. If the potential of the electric railway systems were increased ten or twenty times it is possible that some injury might result to trees even under ordinary moisture conditions.

Probably the amount of ground leakage occurring through imperfect rail connections would not cause any perceptible injury to trees. Nor is there any direct evidence that lightning arrestors when placed near trees cause any injury by discharges. However, the guy wires used by electric railway systems are a source of danger from lightning, and we have observed cases where large limbs have been destroyed and the trunks of the tree badly lacerated by electrical discharges from these wires.

On the whole, the cases of death to trees from electricity are by no means so numerous as is generally believed. Because a large number of trees near electric roads, etc., often look sickly it must not be concluded that electricity is always the cause. In cities and towns, where most of these unhealthy specimens are found, there are innumerable destructive factors for trees to contend with. It is quite essential in diagnosis work, therefore, that all of these factors be taken into consideration before a definite opinion in regard to the cause of any abnormal condition is formed.

Electrolysis.

Direct current electricity is frequently responsible for electrolysis of gas and water mains, and lead coverings of underground telegraph circuits are often affected. The trouble is often so serious that the iron gas and water pipes (Fig. 9, Plate III.) become corroded and eaten with holes in a few weeks or months, causing leakage. When gas mains are affected by electrolysis, the gas escapes and permeates the soil, so that electricity sometimes becomes a primary and gas a secondary factor in the death of trees.

The phenomena associated with electrolysis are often complex and difficult to do away with entirely, according to expert electricians, but much of the trouble can be eliminated by proper bonding of the rails of electric roads and the grounding of different systems.

Electrolysis is more common in wet than in dry soils. Cases are on record where severe electrolysis has taken place 700 or more feet from the source of leakage. It more often becomes troublesome in cities where numerous railways and public-service corporations of all kinds make use of the streets. We have observed cases where plants have been stimulated and their growth increased by escaping electricity in the soil.

LIGHTNING.

The common effects of lightning strokes on trees are so well known that it is not necessary to dwell upon them here; but lightning does not always strike a tree in the same way, and the peculiar effects sometimes produced are often interesting. Very powerful discharges of lightning act somewhat like an avalanche, causing a severe shattering of the tissue, while less powerful discharges may remove a strip of wood only a few inches wide and 1 or 2 inches thick. Lightning often takes a spiral course, following the grain of the wood, which is sometimes very irregular. Even when strips of wood 4 or 5 inches wide and 2 or 3 inches thick are removed, in which case the electrical energy is enormous, the path of the discharge is shown only by a dark-colored streak 2 or 3 millimeters wide.

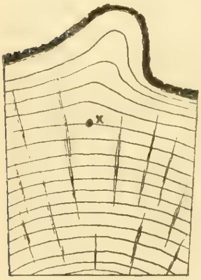

FIG. 11. — Cross-section of elm shown in Fig. 10; X = small dead area corresponding to path of lightning discharge.

Sometimes trees are killed outright by lightning without being shattered or displaying any other of the common effects. In such cases the discharge is apparently dispersed so as to cause no visible mechanical injury to the tree, but the girdling of a large or small area of the living zone or cambium layer of the trunk would be sufficient to cause its death. However, in a very large number of instances neither death nor mechanical injury of any importance takes place. Hundreds of trees are annually struck by lightning that never show any effects except to those capable of interpreting the small narrow ridges which later make their appearance on the trunk. (See Fig. 10, Plate V.). In such cases the lightning discharge follows the line of least resistance, — the cambium zone, — burning a small channel usually about 1 millimeter in diameter. The tissues surrounding the channel are apparently not injured, but the annular rings which are later formed outside the burned channel are much broader, resulting in the formation of a ridge on the bark. (See Fig. 11.)

Earth Discharges.

There are many cases of lightning that are apparently earth discharges. Their effect on the tree is quite characteristic and not at all similar to the ordinary forms of lightning strokes. Our attention was called several years ago to some shade trees to which lightning had apparently caused some injury. These trees were maples 5 to 18 inches in diameter, growing in soil composed mainly of gravel containing oxide of iron, and underneath this a stratum of quicksand. A considerable number of the trees showed the effects of repeated earth discharges, in some cases becoming so disfigured that they had to be replaced for the third time. These discharges occur during thunder storms, and those who have observed them for many years relate that they give rise to a dull, characteristic report resembling that caused by throwing a wet cloth on a hard surface. The whole tree is not affected as a rule, as the lightning stroke seldom follows up the main trunk, but discharges at the points of several branches. As a rule, however, one side of the trunk and one or more of the limbs on that side are affected and the symmetry of the tree destroyed. The first indication of the discharge is shown by the immediate wilting and subsequent death of the leaves of the affected limbs, which also die later. In the course of time cracks similar to those caused by frost, and later, ridges due to healing, will be seen on the trunk, showing the path of the discharge, and occasionally when the injury is considerable the bark falls off near the affected part of the tree. The limbs, however, are not always killed, frequently splitting (see Fig. 12, Plate V.), and a cracking of the wood for some depth is now and then observed on the trunk and limbs along the path of discharge.

A very much larger number of trees show earth discharges than is realized. MacDougal[1] has called attention to some trees which appear to have been injured by earth discharges.

Whether the chemical composition of the soil has any particular bearing on earth discharges is not positively known. It is known, however, that there frequently exist great differences in the electrical potential between the earth and air during thunder storms, and that the electrical conditions of the atmosphere and earth may change instantly from negative to positive. Some observations made in our laboratory with a Thomson self-recording quadrant electrometer and water-dripping collector show that the electrical potential of the atmosphere varies from a negative charge of 75 volts to 300 positive at various times at a distance of 30 feet from the ground; and our records show that most of the time the atmosphere is charged positively. It is also known that trees occasionally discharge sparks at their apices, showing that insignificant earth discharges occur through trees; and when the soil in which potted plants are growing is charged electrostatically, small sparks are thrown off from the leaves. Earth discharges through trees, whether strong or weak, appear to be similar in nature, and may be associated with changes in the potential of the earth and atmosphere. The high electrical resistance shown by plants in general, as already stated, serves as a great protection against death from lightning and electric currents.

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[1] Journal of the N. Y. Bot. Gardens, Vol. III., No. 31, July, 1902.

Susceptibility of Different Trees to Lightning Stroke.

There has always been great difference of opinion in regard to the susceptibility and non-susceptibility of various trees to lightning, and the data on the subject gathered from this and that source are altogether too meager to admit of reliable statistics. But it is known that the location of the tree, nature of the soil, elevation, etc., are of great importance in determining susceptibility to lightning.

It has already been pointed out that electrical resistance is influenced by temperature, and the percentage of moisture in the tissues is also an important factor. During thunder showers trees become more or less drenched with rain, and according to Stahl,[1] the more thoroughly wet the tree is the less susceptible it becomes to lightning stroke. He bases his observations on the fact that smooth-bark trees like the beech and others, which are considered more immune to lightning, become thoroughly wet during storms, while the oak and other rough-bark trees do not. Stahl's idea, therefore, is that smooth-bark trees possess a better water-conducting surface and have a tendency to equalize the electrical tension existing between the atmosphere and the ground, so that they are rendered less susceptible to lightning. His deductions were based upon experiments with electrical discharges made with the bark of different species of trees containing various percentages of moisture. He further observed that vertical limbs were more likely to become drenched than horizontal, and that the lenticels and stomata play a rôle in the equalization of the differences in electrical potential existing between the tissues and the atmosphere, etc. There appears to be no difference in the electrical potential under deciduous trees and in the open air when there is no foliage, at corresponding heights, and the electrical potential will average 40 per cent. less under the foliage of trees than in the open air when the foliage is developed.

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[1] Stahl, E. Die Blitzgefährdung der verschiedenen Baumarten, Jena, G. Fisher, 1912.

The potential of the air is usually negative, although occasionally changing to positive. In the case of coniferous trees, however, like the Norway spruce,[1] we found that the potential under the foliage was invariably positive or similar to that of the earth, which may be explained on the theory that conifers are constantly discharging positive electricity to such an extent that the air surrounding them becomes charged similar to the earth. To what extent the film of water on the bark is capable of equalizing the difference in electrical potential in the air surrounding the trees, as well as the ground and in the tissues themselves, has not been wholly determined, but we had difficulty in obtaining potential readings under the foliage of elms in wet weather in our experiments covering two summers. This may in part be explained by the improper installation of our collector. It is not unlikely that the film of water on the bark of trees during such periods would have a tendency to affect materially the potential of the surrounding air, and possibly to equalize the electrical tension. The subject should have further investigation, but we believe that it is possible to protect trees from injury by lightning, whether they be atmospheric or earth discharges.

METHODS OF PREVENTING INJURY TO TREES FROM WIRES.

The constantly increasing use of electricity for various purposes makes necessary a more extensive use of wires which have become a great menace to shade trees. The appearance of streets is also hardly improved by the increased number of poles and wires, and the legal restrictions as to the height, distance apart, etc., of the wires of the telephone, telegraph, trolley and electric light companies make the problem of maintaining shade trees on the same street with public-service corporations a serious one. Of all the troubles with which tree wardens have to contend the wire problem is often regarded as the worst. Notwithstanding the strict laws which some States have adopted in regard to injuring shade trees, the agents of some public-service corporations often have little regard for trees or the laws respecting them. Where 40-foot poles must carry the wires of three or four public-service corporations there can be little or no opportunity to preserve the natural symmetry of shade trees, especially when low branching maples and other trees are planted on the same side of the street with the wires. There is less interference from limbs with low than with high-tension wires. Trees like the elm, whose branches form acute angles, offer less obstruction to wires than maples; but not all streets, of course, are planted with elms, which may be as well, considering their susceptibility to various pests and unfavorable climatic conditions.

The best solution of the wire problem lies in burying the wires. This has been done to quite an extent in large cities, especially in the business sections, the telephone corporations having adopted this system to a much greater extent than the electric light companies. It is an expensive system, however, and those who so strenuously advocate its adoption do not always consider that in the end it is the patrons who have to pay for it.

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[1] Mass. (Hatch) Agr. Exp. Sta. Rept. 1905, p. 14.

Another method of preventing wire injuries is the erection of high poles to bring the wires over the trees. This is sometimes done, especially where the trees are young or of a species that naturally grows low, when a very high pole would be sufficient to clear them for many years. The cable system may be used for telephone wires, and much injury to trees prevented. Large cables are rather expensive to install, but what is termed the "ring construction" system may be used to advantage in many instances, particularly in the suburbs. In this way it is possible to run a line through avenues of fine trees in the country districts without necessitating pruning or disfiguration.

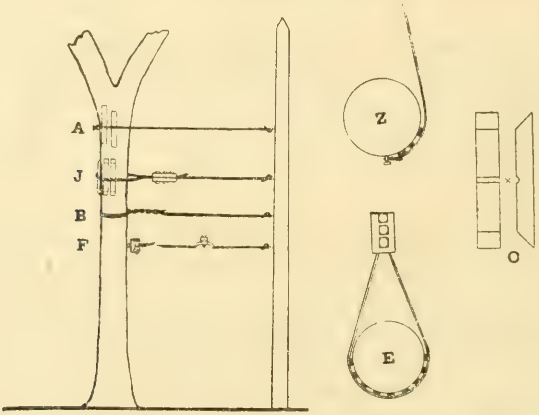

FIG. 13. — Showing different methods of attaching wires to trees: *a*, wire attached to lagbolt, and tree protected from it by wooden blocks; *z*, cross-section of same; *b*, wire loops placed tightly around tree, causing girdling; *f*, showing attachment of trolley guy wires; *j*, loose loop fastened with clamps and separated from tree by blocks; *e*, cross-section of same; *o*, creosoted oak blocks with groove *x* to support the wire.

Rights of way for poles on private property back of residences are sometimes secured, and by this means the poles and wires may be removed from the streets, much to the advantage of the trees. But such rights are often difficult to secure, and are not always satisfactory either to the public-service corporations or the owners of the property. The former naturally do not care much for these rights of way unless they are legal and permanent, and the owners in granting permanent rights run a risk of lowering the value of the property. Most of the very high-tension transmission services, however, are at present on private property and seldom interfere with trees. High-tension lines are affected seriously merely by close proximity to trees; therefore these rights of way have to include broad strips of land, which of course is expensive.

On general principles it is not wise to allow wires to be attached to trees, although this is often done. Trolley and electric light wires are frequently guyed to trees, but they are a source of danger, since injury is likely to occur from the crossing of the wires, and lightning discharges occasionally pass from the wires to the tree, causing damage.

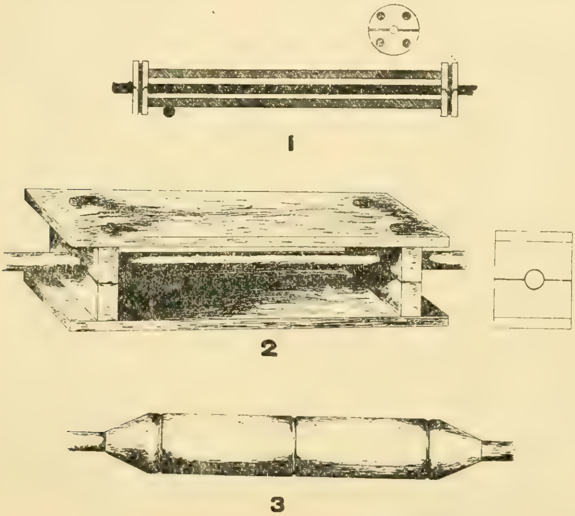

FIG. 14. — Showing different types of guards for electric wires: 1, porcelain dowel guard; 2, porcelain wood guard; 3, wooden sleeve.

It is, however, often better to allow this than to endure the erection of ugly poles; but proper insulation of the wires should be insisted on, although ordinary insulators have little effect on lightning discharges. The lagbolt system in common use for guying wires to trees is not the best method, for sooner or later the wire and bolt become imbedded in the tree and cause injury. Moreover, a direct metal connection with a tree is objectionable, as it has in more than one instance proved. The block system is better, although it may not in all cases be free from objections. In no case should a wire be allowed to pass tightly around a tree, as it will girdle it in time. When live wires come into contact with limbs, some type of insulator should be employed similar to that shown in 1, Fig. 14, of which there are various types, some being quite effective in preventing injury from low-voltage lines. The type shown in Fig. 14, No. 2, is cumbersome and unsightly, but is one of the most effective. The principle of the porcelain and dowel insulator is good, but it has a tendency to slide on the wires and become displaced. If it were provided with larger dowels, and the danger of displacement on the wires done away with, it would prove much more satisfactory.

Wires often accidentally come into contact with trees by the displacement of poles, particularly on curves, where the strain is very great, but much of this injury may be prevented by imbedding the poles in Portland cement. It should be pointed out that the necessity for guying poles to trees may be obviated in this way.

Better methods of handling this vexatious question of wires and shade trees should be forthcoming in the future, and even at present there must be a compromise between the tree warden or city forester and the companies as to the best method of wiring through tree belts and the amount of pruning allowed. Conditions at present favor the corporations, as they are furnishing valuable and necessary facilities for business, etc., and in towns they obtain their franchises and location of poles from the selectmen with little difficulty. The selectmen notify the abutters of any contemplated installations of poles and wires or of changes to occur in the systems, and the abutters are given a hearing. However, they usually wake up to their duty only after the installation of the lines, when the tree warden must assume all responsibility for injury to the trees. He has to choose between two courses, — prevent the pruning or permit it. In either case the companies can erect the poles and install the wires, allowing the wires to burn their way through the trees, although this, of course, often causes trouble to the corporation as well as to the consumer. In case of injury to trees the warden has access to the courts, but most companies are willing to put up with a few moderate fines for the sake of the right of way through a tree belt.

SUMMARY.

Electricity acts as a stimulus to plants. The minimum and optimum current strengths probably differ little in different plants. The maximum current, or that necessary to kill a plant, is quite variable.

Outside of the disfiguration to trees from pruning necessitated by wires, the greatest injury consists in the local burning and often partial destruction of the tree caused by high-tension line wires.

There is practically little or no leakage from wires during dry weather. In wet weather, however, when a film of water is formed on the bark, more or less leakage occurs, and if the insulation is insufficient, grounding takes place and burning, due to "arcing," results.

No authentic cases have been observed by us where the alternating or direct currents as ordinarily employed have killed trees; but instances are known in which the death of trees has taken place when the polarity in electric railway systems have become reversed; *i.e.*, the rail becoming positive and the feed wire negative.

The burning is more pronounced at the positive electrode than at the negative, and when the current is reversed a larger area of tissue is affected. The burning arises from the heating of the film of water on the bark, which destroys the live tissue underneath.

The high resistance offered by trees and plants in general serves as a protection against severe injury from lightning and contact with high-tension line wires.

The least resistance in trees occurs in the vital layer (cambium) and adjacent tissues.

The electrical resistance of trees is influenced materially by temperature and moisture.

The physiological effect of the direct current on vegetable life differs from that of the alternating.

There is evidence to support the idea that a direct current of not sufficient strength to cause burning may electrolize the cell contents and later result in the death of the tree.

Earth discharges during thunder storms are more common than generally supposed, and are known to disfigure and cause the death of trees.

PLATE I.

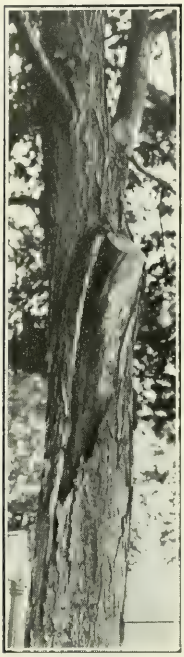

FIG. 1.—Showing maple tree injured by lightning discharge from trolley guy wire, causing death of limb and laceration of trunk.

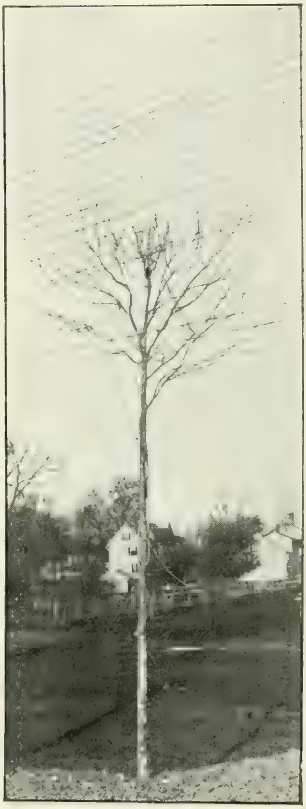

FIG. 2.—Showing the destructive effect on the growth of a maple tree of a mass of wires.

PLATE II.

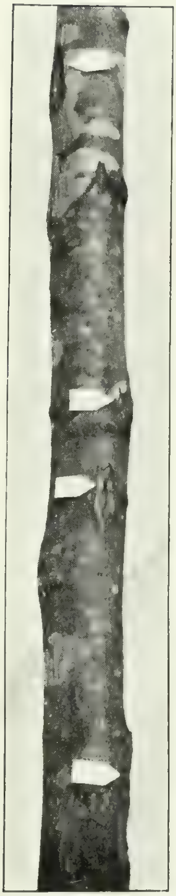

FIG. 4.—Showing injury to young maple tree by linemen's spurs.

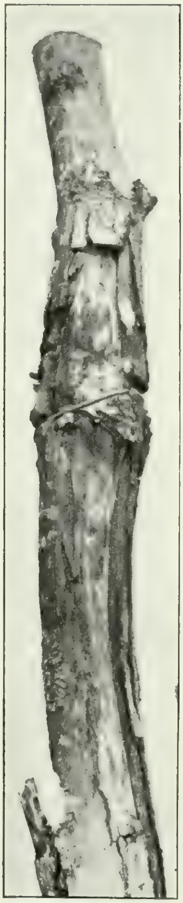

FIG. 5.—Showing the effects of strangulation by wires.

PLATE III.

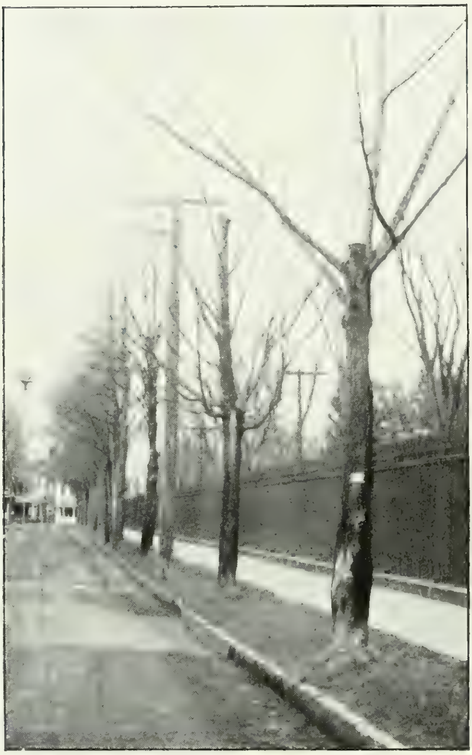

FIG. 6.—Showing disfigurement of trees caused by high-tension alternating current wires.

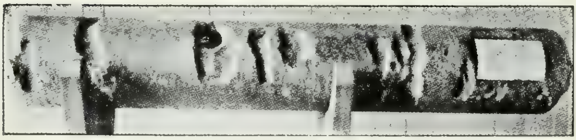

FIG. 9.—Showing electrolysis of gas pipes. (After A. A. Knudson, "Corrosion of Metals by Electrolysis.")

PLATE IV.

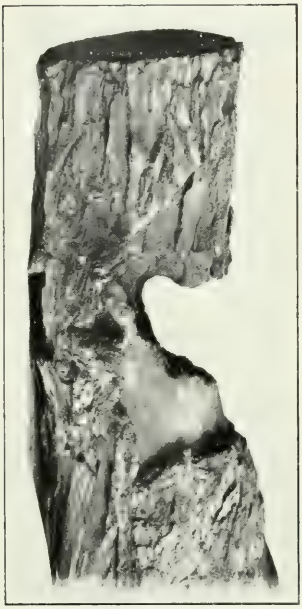

FIG. 7.—Showing deep burning of large limb by high-tension alternating current wire.

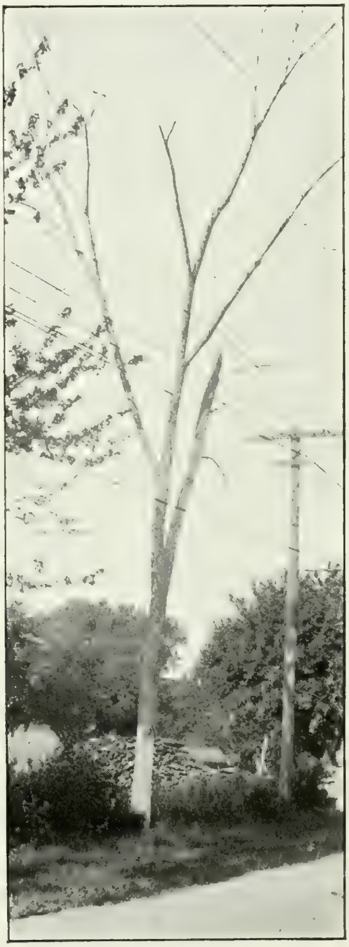

FIG. 8.—Showing elm tree killed by direct current (reversed polarity) from electric railway system. Note effects of burning at the base of the tree.

PLATE V.

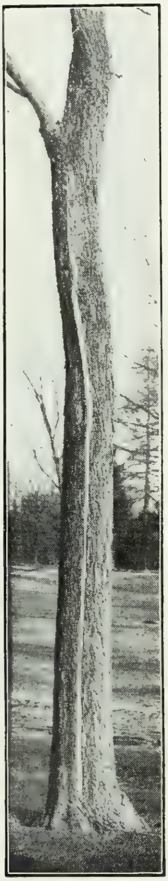

Fig. 10. — Showing ridge on elm tree caused by feeble lightning discharge.

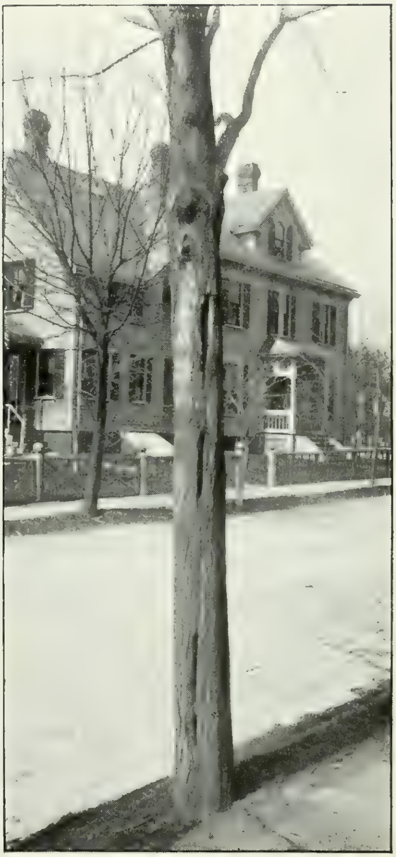

Fig. 12. — Maple showing effects of earth discharges (lightning), causing splitting of the trunk and death of limbs.

BULLETIN No. 157 NOVEMBER, 1914

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

THE MARGUERITE FLY

(Phytomyza chrysanthemi Kowarz)

By M. T. SMULYAN, B.S.

THE LIFE HISTORY, HABITS AND METHODS OF CONTROL OF THIS GREENHOUSE PEST

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THE MARGUERITE FLY OR CHRYSANTHEMUM LEAF MINER.

(*Phytomyza chrysanthemi* Kowarz.) (Order, *Diptera;* Family, *Agromyzidæ.*)

M. T. SMULYAN, B.S.[1]

INTRODUCTION.

The growing of plants under glass is an important industry in Massachusetts, and is becoming more so every year. Among the plants which are of ornamental value, or are raised for their flowers, marguerites or daisies, chrysanthemums and other Compositæ are very generally grown, the two former often on a large scale. It is not at all surprising, then, that complaints are heard on all sides regarding the ravages of the Marguerite Fly, or Chrysanthemum Leaf Miner. Indeed, in many instances, the commercial growing of marguerites and some other Compositæ has been given up on account of this pest.

At the time the writer began the investigation of this troublesome insect it was not generally known that there were one or two florists in the State who possessed a satisfactory method for its control, though such was the fact.

The investigations upon which this paper is based were carried on in the insectary and laboratories of the Department of Entomology of the Massachusetts Agricultural College, Amherst, under the direction of Prof. H. T. Fernald and Dr. G. C. Crampton. The investigations were begun early in February, 1913, and continued to July of the same year, in connection with the marguerite, or cultivated daisy, as a food plant. Some additional data relating to the life history of the insect were collected during the following November. The thanks of the writer are due both to Professor Fernald and Dr. Crampton for their interest in the work, and for a number of valuable suggestions. The writer is also under obligations to Mr. Walker Holden of Andover for furnishing infested marguerites for study, and to the latter again and to Mr. W. R. Nicholson of Framingham for their readiness in answering questions, many of the answers proving very helpful.

---

[1] Contribution from the entomological laboratory of the Massachusetts Agricultural College. Part of a thesis for Ph.D. degree.

The methods and appliances used in connection with the work are all very simple. The methods are described in the various sections which follow. The habits of the adults were studied very largely with the aid of an ordinary pocket lens while the flies were at large upon the host plants in the insectary. In the study of the other phenomena relating to the adults, cheesecloth bags possessing a certain degree of stiffness were found very useful. In the laboratory, for the study of the various stages, habits of the larva, etc., an ordinary compound microscope and a Zeiss-Greenough binocular were found indispensable.

The outlines of the drawings, except that of the adult, were all made by means of the camera lucida. The photographs were taken by T. W. Nicolet under the direction of the writer.

HISTORY AND DISTRIBUTION.

The Chrysanthemum Leaf Miner, Chrysanthemum Fly, Marguerite Leaf Miner, Marguerite Daisy Fly, or the Marguerite Fly, as the insect is variously called, was first detected in this country, according to Dr. Lintner (Fourth Report on the Injurious and Other Insects of the State of New York, 1888, p. 73) in October, 1886, in the greenhouse of Mr. Chas. A. Dana, near Glen Cove, N. Y. Dr. Lintner writes: "The leaves of some daisies (marguerites) were seen to show some wart-like specks and irregular, whitish, linear markings, and soon afterward to shrivel up and die. Examination for the cause disclosed very small 'worms' working within channels in the interior of the leaves." Some of the infested foliage was sent to Dr. Lintner in Albany the following February. The operations of the insect were first noticed by Mr. Wm. Falconer, head gardener at "Dosoris."

Mr. Falconer reported this discovery independently in the "American Florist," March 15, 1887 (Vol. II., p. 297). "This little pest," writes Mr. Falconer, "made its first appearance here last November." (There is a slight discrepancy between the statements of Dr. Lintner and Mr. Falconer regarding the first appearance of the fly in the greenhouse; according to Dr. Lintner it was October.) "Before then I was not aware of its presence in this country, but since then I find it as abundant in greenhouses at Glen Cove Landing and at Hinsdale as it is here." (Mr. Falconer, like some others at the time, thought the insect a European species.) "I first observed its presence by noticing little wart-like specks and irregular, whitish, line-like markings on the leaves of some of the marguerites, and these traces soon multiplied exceedingly and the much-affected leaves withered up and died. The fly is a small insect and might readily be mistaken for one of the little flies so abundant about fermenting horse manure. When disturbed it 'hops' about rather lazily or flies from one branch to another, but seldom flies away more than a few feet. It lays its eggs singly under the skin of the leaf, the wart-like specks forming over the eggs. In a few days' time the little white grubs are hatched; these are the evil workers. They devour the fleshy substance between the skins of the leaf, eating their way in irregular lines or broad patches, and these are the whitish markings observable on the surface of the leaf. After two weeks of energetic eating it thrusts its head outside of the skin of the leaf and pupates. From the laying of the egg till the perfect insect issues from the chrysalis is within five weeks."

Dr. Lintner (Fourth Report on the Injurious and Other Insects of the State of New York, 1888, p. 76) mentions Queens, Long Island, as another locality where the insect was present at about the same time it was operating at Glen Cove Landing and Hinsdale.

The depredations of the fly seem to have been noticed elsewhere in New York about the same time, infested chrysanthemum leaves having been received from Mr. Charles Anderson of New York by the Department of Agriculture at Washington, Dec. 30, 1886. (Coquillett, Insect Life, VII., 1894–95, p. 399.)

Two weeks later, Jan. 14, 1887, infested marguerite leaves were received by the Department of Agriculture at Washington from Prof. Thomas Meehan of Germantown, Pa.

In 1889 the insect was found mining in the leaves of Japanese chrysanthemums (in the Arnold Arboretum?), near Boston, Mass. (F. J. Jack, Garden and Forest, III., 1890, p. 440), and according to Mr. Jack it had been troublesome in other places in the vicinity of Boston, mining in the leaves of chrysanthemums, eupatoriums and cinerarias in greenhouses. (Lintner, Seventh Report on the Injurious and Other Insects of the State of New York, 1891, pp. 244, 245.)

In 1890 infested marguerite and feverfew leaves were received by the Federal Department of Agriculture from Irvington, N. Y., Danbury, Conn., and Brooklyn, N. Y. (Coquillett, Insect Life, VII., 1894–95, p. 400.)

In February, 1893, infested cineraria leaves were received by Dr. Lintner from the greenhouses of St. Vincent's Male Orphan Asylum, Albany, N. Y. (Tenth Report on the Injurious and Other Insects of the State of New York, 1895, p. 510.)

In April, 1907, Mr. C. W. Johnson of the Boston Museum of Natural History received specimens of the adult fly for identification from Prof. E. D. Sanderson of New Hampshire, indicating that it was causing trouble in that State about that time.

In 1911 it was reported in Connecticut again. (Britton, Eleventh Report of the State Entomologist, 1911, p. 342.)

In 1912 it was discovered mining marguerites in a greenhouse in Helena, Mont. (Cooley, Tenth Annual Report of the State Entomologist, Bull. No. 92, November, 1912, p. 56.)

During the spring and summer of the same year a very serious outbreak occurred in some greenhouses in Milwaukee, Wis., which had imported infested chrysanthemums and marguerites from Boston, Mass. It was also reported from Chicago "and other parts." (Sanders, Journal of Economic Entomology, Vol. V., No. 6, December, 1912, p. 472.)

Since 1899, no data being available previous to that year, at least five complaints have been received from various parts of Massachusetts by Dr. H. T. Fernald, Entomologist for the Massachusetts Agricultural Experiment Station. The last complaint was made in January, 1913, by Mr. Walker Holden of Andover, and led to the investigation of the pest by the writer. Replies to inquiries made during the summer and fall, however, indicate that the pest is generally distributed throughout the eastern part of the State.

FOOD PLANTS.

Falconer, in his account of the insect in the "American Florist," states that while the marguerite (*Chrysanthemum frutescens*) seems to be its favorite food, it does not at all restrict itself to this plant, but attacks every other plant of the family Compositæ within reach. It appeared to Mr. Falconer that it even preferred the double white feverfew (*Chrysanthemum parthenium*) to the marguerite. He mentions *eupatoriums, gazanias, Helianthus decapetalus* var. *multiflorus*, and *Senecio* (*Cineraria*) *cruentus* as also having been attacked. Dr. Lintner received from the same greenhouse infested leaves of the tansy (*Tanacetum vulgare*) and of three other Composite species which he did not identify. As already stated, the common greenhouse chrysanthemum (*Chrysanthemum indicum, C. morifolium* or *C. sinense*) was very early noticed as a food plant. This completes the list of food plants recorded, so far as the writer has observed.

During the writer's investigations, however, adult flies were reared from a number of additional species of plants of the family Compositæ. These plants, though growing in the greenhouse, are not normally greenhouse plants, but had (with the exception of one, — *Helianthus annuus*, the common annual sunflower, which was growing in the greenhouse of the Department of Botany, and was found infested the following fall) simply been allowed to grow, together with a number of other weeds, in the hope that new food plants might perhaps be discovered. These plants are *Solidago nemoralis*, goldenrod; *Ambrosia artemisiifolia*, ragweed; hogweed, etc.; *Taraxacum officinale*, dandelion; *Bidens frondosa*, beggar ticks; *Daucus carota*, wild carrot; *Chrysanthemum leucanthemum*, the common white or ox-eye daisy; and *Antennaria plantaginifolia*, everlasting or ladies' tobacco.[1]

The discovery of the above food plants suggested that the pest could lead an outdoor existence, even in absence of its cultivated food plants, and, surely enough, during the last days of April some dandelions growing at the foot of the greenhouse were found infested.

The flies apparently did not venture from the immediate vicinity of the house. Only the plants at the foot of the house were attacked, and numerous observations which continued into late June failed to disclose others infested. The following December, however, the writer discovered the flies in the greenhouses of the botanical and floricultural departments, somewhat removed from the insectary, where they had been attacking for some time sunflowers, marguerites and cinerarias.

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[1] These plants were kindly identified by Mr. Geo. H. Chapman and Prof. A. V. Osmun of the Department of Botany.

Falconer's observations, to the effect that the insect shows a strong partiality for marguerites, seem to have been correct. Chrysanthemums in close proximity to the marguerites in the insectary were only very slightly attacked. A very strong inclination was manifested for the dandelion, goldenrod, ragweed, and ox-eye daisy, however. These were badly injured and were much preferred to the white marguerites; indeed, after these plants became numerous and large, the white marguerites were almost entirely neglected. The yellow marguerites, on the other hand, remained favorites, and continued to be badly infested.

NAME.

In the earliest published report on this insect by Falconer in the "American Florist," it was designated *Phytomyza affinis* Fallen, the name having been taken from a species which was doing similar injury to plants in Europe, and which now occurs in North America.

Dr. Lintner, however, obtaining specimens of this insect and finding it unknown to him, submitted the adult fly, together with its pupæ and larval mines, to Baron Osten Sacken, who identified it as the European species *Phytomyza lateralis* Fallen. It was thus designated by Dr. Lintner in his report on this insect in his fourth annual report.

Somewhat later, other specimens found mining chrysanthemums and other plants in the vicinity of Boston by Mr. J. G. Jack, and believed by him to be *Phytomyza nigricornis* Macquart, were forwarded by Mr. Jack to Baron Osten Sacken for determination. On examination these were found to be the same as those previously submitted by Dr. Lintner and which were identified as *Phytomyza lateralis* Fallen; but as they did not correspond with *P. lateralis*, Osten Sacken realized the mistake he had made and lost no time in notifying (early in 1890) Dr. Lintner, writing in part, as follows: —

> I am very sorry to acknowledge that I must have misled you in this case by a wrong determination. I do not remember now under what circumstances I committed the blunder and what prevented me from sending the specimens to Kowarz.

The examples from Mr. Jack were then sent by Osten Sacken to Kowarz. Unable to identify the insect with any known European species, Mr. Kowarz described it as a species new to science, and named it *Phytomyza chrysanthemi*. The description, translated by Osten Sacken, was first published in this country in Dr. Lintner's "Seventh Report on the Injurious and Other Insects of the State of New York," 1891, p. 243.

Aldrich in his "Catalogue of North American Diptera" (1905) lists it as *Napomyza chrysanthemi* Kowarz (*Napomyza* originally a subgenus of

Phytomyza, but now raised to generic rank by some writers), but this is clearly an error, as the keys in the literature referred to in the catalogue place the insect in the older genus *Phytomyza*, the posterior cross vein being absent in *chrysanthemi*.

Sanders (Journal of Economic Entomology, Vol. V., No. 6, December, 1912, p. 472) has already referred to the insect by this catalogue name.

INJURIES.

(Plates II. and III., Figs. 9, 10, 12.)

The first indications of the activity of the insect are seen in minute, pale specks, blotch-like, and usually fan-shaped, on both surfaces of the leaves (Fig. 9). As a rule, they are more numerous on the upper side. These specks or blotches are produced by the adult female fly, which pierces the epidermis and destroys the parenchyma beneath by means of her ovipositor, for the purpose of feeding or egg laying.

These blotches, however, do not long retain their original appearance. In a few days, as a result of a reaction on the part of the injured parenchyma, they usually develop into wart-like protuberances or papillæ (Fig. 9); and when the flies are abundant, during a period of great activity, the surfaces of the leaves may be literally covered with the papillæ, or papillæ and blotches together. On the other host plants which were kept under observation in the insectary the papillæ developed less readily, and as a rule, less perfectly.

The real damage, however, is caused by the larva or maggot. Seemingly possessed of a tireless energy and of appetites which never seem to be satisfied, the maggots move slowly along beneath the epidermis (most of the feeding is done immediately beneath the epidermis of the upper surface) of the leaf, devouring the parenchyma in their course, and leaving a whitish and usually irregular path — the external evidence of the mine which lies directly beneath — in their wake, the white color of which contrasts sharply with the green color of the rest of the leaf surface (Fig. 10). The mine widens and becomes more distinct as the larva increases in size. The part of the leaf thus mined (the petiole very often also), or the whole, if it is badly attacked, gradually dries up, and in this withered condition remains clinging to the plant (Fig. 12). Small plants may be killed in a comparatively short time during a period of great activity of the flies.

In reply to some questions of the writer in regard to the resulting injury, Mr. Walker Holden, who kindly furnished the infested marguerites for study, states that "the infestation reduces the number of flowers and weakens the plants to a very great extent." Moreover, he is of the opinion that, because of the reduced vigor of the plants, there is a tendency towards a reduction in the size of the flowers.

Of the plants (feverfews, yellow marguerites, and white marguerites) attacked in Mr. Holden's greenhouse, the yellow marguerites were the most seriously affected — so seriously that he destroyed them. Of the two yellow marguerite plants kept under observation in the insectary, one did not bloom until June (the plants were received early in February), when the flies in the house had decreased and the attack had considerably abated, while the other produced no flowers at all — at least up to July 5, when the writer left Amherst for the summer. Buds in many instances formed, but they dried up after reaching a certain size. The following December the two yellow marguerite plants were dead.

IMPORTANCE OF THE PEST.

The wide distribution of the insect, the large number of commercially grown plants it attacks, the numerous complaints, — many of these reporting serious injury, — all attest and bear testimony to the seriousness of its depredations.

As far back as 1890, Mr. J. H. Ives of Danbury, Conn., writing to Coquillett of the federal division of entomology, stated that he would be compelled to abandon the growing of such plants as marguerites and feverfews, owing to the attack of this pest.

According to Britton (1911) the damage in Connecticut has been so great in some instances that the growers had to abandon the commercial growing of such plants as chrysanthemums, marguerites, feverfews, cinerarias, eupatoriums and tansies.

Sanders (1912), in reporting an outbreak in Wisconsin, states that the growers were facing an entire loss of their flowering plants caused by a complete infestation of the leaves.

Mr. Walker Holden, in reply to a letter of the writer, closes as follows: "I shall be very glad to help out in any way I can to conquer this pest, for it is surely a pest."

Fortunately, no great fears, it seems, need be entertained in regard to the insect as an outdoor pest, it appearing to be essentially an indoor or greenhouse insect. If provided with food, it will remain in the greenhouse all summer, although in reduced numbers. In addition to its being essentially a greenhouse pest, it is apparently also essentially a moderate-temperature insect, seeming to find its most congenial conditions in a temperate and somewhat humid atmosphere. The writer had noticed a considerable falling off in its numbers even before he left Amherst for the summer (first week in July). This could not be explained entirely on the ground that some had left the insectary to take up an outdoor existence, for those that left apparently remained in the vicinity of the insectary, and their numbers could therefore be observed. The hot, sunny, dry atmosphere in the insectary, it seems, is a much better explanation of the decrease. Such an environment may cause itself to be felt in a number of ways. It may diminish the egg-laying powers of the female; it may cause a reduction in the percentage of eggs hatching; it may cause the death of certain larvæ (the writer found both eggs that failed to hatch and dead larvæ in a number of instances in late June), etc. It is quite likely that the numbers of the insect are reduced in a measure in all these ways. The fact that the insect has not been reported as an outdoor pest throughout all these years is very strong additional evidence that it is only a greenhouse pest.

LIFE HISTORY AND HABITS.

The Adult. (Plate I., Figs. 1, 2.)

Description.

The following description, taken from Dr. Lintner's " Seventh Report on the Injurious and Other Insects of the State of New York," 1891, p. 243, is Kowarz's original description of the insect, made from twenty specimens which were submitted to him by Osten Sacken in 1890, and published for the first time in this country in the above report: —

> Front and face yellow, occiput gray, antennæ altogether black, tip of the palpi generally dark, oral bristles distinct, genæ narrow, hardly equal to one-third of the height of the eye. Thorax and scutellum uniformly gray, sometimes the former with a pale-yellow lateral stripe in front of the root of the wings; thoracic dorsum usually with four pairs of dorsal macrochetæ, but without the intermediate acrostichal [or inner row of the dorso-central] bristles; seldom a few in the vicinity of the scutellum; scutellum with four macrochetæ on the edge. Wings almost hyaline; veins blackish, yellowish near the root; the costal vein reaches the tip of the third vein only, which tip is rather far distant from the tip of the wing; the first, second, and third veins are distinct, the other longitudinal veins are thin, especially the fourth, which ends in the tip of the wing; the sixth vein is incomplete; the posterior cross vein is wanting; tegulæ and halteres pale yellow. Legs black only the knees pale yellow; sometimes also the trochanters of the fore legs yellow. Abdomen black, but little shining, the ventral sides more or less distinctly pale yellow; the posterior edge of the anterior segments with an exceedingly narrow pale-yellow margin; on the last segment this margin is more distinct. Genitals black, those of the male of moderate size; the ovipositor of the female hardly as long as the last abdominal segment.

The following additional minor observations may be appended: eyes red when insect is alive, black when dead; wings somewhat iridescent; the yellow on the ventral sides of the abdomen gradually narrowing from base to apex. Whereas the abdomen in the male tapers gradually and ends bluntly, that of the female ends somewhat pointedly, the last segment having the shape of a truncated cone. Length of body of male 2 millimeters, female slightly larger; this somewhat larger size of the female is especially marked during the egg-laying period.

According to Kowarz this species bears a close resemblance to *Phytomyza affinis* Fallen, but differs from the latter in the absence of the acrostichal bristles and in the shorter ovipositor.

Habits of the Adult.

In common with many other Diptera or flies, the marguerite flies lack the power of strong and long-sustained flight. They crawl lazily about, or make their way from leaf to leaf and from plant to plant in a skipping or hopping flight, very seldom flying more than a few feet at a time. The periods between flights may be quite long, unless the flies are disturbed, and great portions of these periods may be spent at rest in one place. The males are, as a rule, more active than the females, the latter being also more tame.

Their activity and degree of tameness vary, also, with the time of day, with the degree of sunlight and with the temperature. They are comparatively tame in the early forenoon, late afternoon and on cloudy days. Inactivity and drowsiness, as might be expected, are strongly marked at lower temperatures. Both males and females are tame while mating and after, although the female remains thus for a much longer period.

While inactive in darkness they at once become active when brought into bright artificial light. They have been observed to mate in such light, and as will be seen later, will even oviposit.

Both sexes are strongly negatively geotropic, seeking, as a rule, the highest point of an object or vessel in which they are confined, a trait which was found very useful, and of which full advantage was taken by the writer during the investigations.

Mating.

Newly emerged flies kept in confinement in the laboratory, to determine how soon after emergence mating begins, yielded rather widely variable results; that is, there was a wide variation in the length of time elapsing between emergence and coupling for different individuals. While most of the individuals which were confined together for this purpose were of about the same age, some were of different ages, the age varying with the one or the other sex. These periods between emergence and mating ranged from approximately six to approximately forty hours, and were more or less scattered between the two extremes. Under natural conditions, with the flies free and at large on plants, the results would probably be modified. For instance, it is doubtful if under natural and normal conditions, with both sexes in abundance, individuals would abstain from mating for so long a period after emergence as did some in confinement in the laboratory. On the other hand, the fact that some united about six hours after emergence, would seem to indicate that in some instances, at least, mating takes place very shortly after emergence.

The length of time that couples remain united also varies. In one instance a couple remained attached for three and one-half hours, in another, two and three-quarters hours, and in another two hours. The more usual period, however, seems to be from one-half to one hour. As compared with the same in other Diptera or flies, this is rather short. The "northern cherry fruit flies," for instance, according to J. F. Illingworth, may remain coupled for eighteen and one-half hours. (Bull. No. 325, Cornell University, 1912.)

The male mounts the female, as a rule, when the female is at rest, by grasping her with his anterior legs and pulling himself up on her back.

He usually draws near gradually, by successive stages, stealthily. Quite a time is spent in covering the short distance, often too much it would seem, for very frequently the female will walk off or fly away before he reaches her. Sometimes, however, he will draw near at once, and, after a period of variable length of almost perfect quiet, will mount her in the usual way, or land on her back, apparently, by means of a well-calculated leap or jump. Not infrequently he may endeavor to mount the female while the latter is engaged in piercing the epidermis of the leaf for feeding purposes.

The sight of a couple in copulation excites the male quickly. It is not unusual to see two males upon one female, and as many as four have been observed. In one instance, in confinement, a male was observed trying to mate with a dead female, lying near by, on being shaken off by a couple already united.

That the instinct for mating is very strongly developed in the males was evidenced by their attempts, when confined together by themselves, without previously having had access to females, to mate with each other. In such cases one male would yield to the other just like a female.

When connected, the male rests upon the back of the female, his anterior legs grasping her thorax on top between the bases of the wings; the wings are spread apart just enough to accommodate the male. His intermediate legs grasp the sides of her abdomen about in the middle, or more usually, somewhat posterior to the middle, the posterior legs grasping the sides of the abdomen at some point beyond. The abdomen of the male curves downward and slightly forward to meet the genital opening of the female, and the last abdominal segment of the latter is normally raised somewhat above its usual level, due to the insertion of the copulatory organ of the male.

During copulation the female with the male upon her back stands quietly in one place, apparently, moving only when disturbed or when she is desirous of ridding herself of him. In the latter case, she is usually very restless, moving about continually, and in addition, endeavoring with great energy to kick him off. The male is perfectly quiet, excepting that now and then he may raise himself slightly and shake himself very violently, as if desiring to break loose.

On separating, the male immediately or soon after flies away. The female, on the other hand, remains quietly in place, or she may move to another part of the leaf and then come to rest. Immediately after, or after a short period of inactivity, she begins to protrude and retract her ovipositor in quick succession, repeating this, as a rule, a number of times, at irregular intervals.

She then engages in what seems like a cleaning operation, brushing the apex of her abdomen with her hind legs, and in turn rubbing these legs against each other and against the wings, the two legs against one wing, the wing being held between them, and each one against the wing on its own side. It should be added, however, that the flies will often engage in this operation at other times than soon after mating.

Mating takes place, as a rule, in the forenoon — becoming less frequent towards noon — and during the latter part of the afternoon. Mating between about noon and the latter part of the afternoon is not very common on days of bright sunlight. On cloudy days it continues uninterruptedly.

As has already been intimated, couples isolated on leaves on plants in the laboratory were observed mating in artificial light.

As might be expected, the males are polygamous and the females polyandrous; that is, a male will fertilize more than one female, and a female will accept more than one male. The number of matings during adult life is probably large, and continues, it would seem, throughout the greater part of the same. A female confined with one male at a time within a cheesecloth bag upon a leaf on a plant accepted two males four times in three days, one of the males twice in as many days, and the other twice in one day. In another instance, a couple which had separated at 9.40 A.M. were coupled again at 2.40 P.M. of the same day, although during this second coupling the female was very restless, moving about considerably, as if she was not at all contented to receive him. As regards how long mating continues, there is a record of a female which emerged April 13 receiving a male May 22, forty days after emergence and seven days before her death; in another instance, a female which emerged April 10 was observed mating May 13, thirty-four days after her emergence and six days before her death.

Feeding.

The females, at least, feed during their adult life, the food being the juices of the leaves of the host plants. To this end the epidermis of the leaf is pierced and the parenchyma in contact with it at that point is cut or macerated by means of the tubular ovipositor.

The process forms a prominent feature of the female's activity, and is an interesting one to watch. Having selected the site — she often tests the leaf surface with the ovipositor — and placing herself lengthwise upon the leaf or leaf-lobe, so that her longitudinal axis is parallel with the longitudinal axis of the leaf or leaf-lobe, she flexes the apical portion of her abdomen downward and forward so that it approaches the leaf surface vertically. The epidermis is then pierced, and the ovipositor, which is but slightly exserted while it pierces the epidermis, is inserted into the leaf horizontally. Then, by means of a series of motions of the ovipositor in longitudinal, diagonal, and sometimes transverse directions, involving the alternate protrusion and partial retraction of the ovipositor, and accompanied by a rotary motion of the abdomen, the parenchyma in contact with the epidermis is cut or macerated. The apical portion of the abdomen is, as a rule, angulated somewhat during the latter part of the operation.

Following the withdrawal of the ovipositor, she backs up, and, applying her proboscis to the aperture previously made, feeds on the juices of the tissue thus exposed, protruding and retracting her ovipositor several times while so engaged. Towards the last of the feeding the proboscis is applied intermittently. The blind end of the incision made is almost invariably directed towards the apex of the leaf or leaf-lobe.

The length of time spent in the process varies. A large number of observations showed a variation of from twenty to one hundred and forty seconds for the piercing and cutting operation, although the more usual was from thirty to sixty seconds, and a variation of from six to one hundred and twenty-nine seconds for actual feeding, the more usual period being from about twenty to forty seconds.

The immediate apparent effect of the piercing of the epidermis by the female and her subsequent cutting directly beneath it is a very small, pale and usually fan-shaped blotch with a minute aperture in its periphery at the point where the handle of the fan would be located. This blotch, which measures roughly from $\frac{1}{2}$ to $\frac{3}{4}$ millimeter by $\frac{1}{2}$ to nearly 1 millimeter, but usually $\frac{1}{2}$ by $\frac{3}{4}$ millimeter, represents the area of the epidermis cut away from the parenchyma. Its paleness, which contrasts with the green color of the rest of the leaf surface, is due to the maceration or destruction of the green chlorophyllous tissue beneath, which imparts the green color to the colorless and closely applied overlying epidermis.

As pointed out once before, these blotches, with the exception of a few, do not retain their blotch-like appearance. Reacting to the injury, the leaf tissue at that point is stimulated to new growth, and, growing outwardly, away from the center, gradually undergrows the elastic epidermal area or blotch and raises it above its normal level, forming a wart-like tubercle or papilla with a single perforation at a point in its periphery. (Plate II., Fig. 9.) On the other host plants under observation in the insectary these papillæ formed less readily and less perfectly.

Feeding is done to a greater extent from the upper surface of the leaf.

Do the males feed upon the juices of the leaf tissue of the host plants as do the females?

Lacking the ovipositor with which the females are provided, the males are of course unable to pierce the epidermis of the leaf. In order, therefore, to feed upon the juices of the leaf tissue they must resort to the punctures made by the females. This, it should be said, the writer has not observed them doing. Experimental evidence, however, as will be seen below, though somewhat contradictory, would seem to indicate that they do.

Thus males live longer when confined with females upon leaves on plants which are pierced by the females for feeding purposes than when isolated by themselves, under the same conditions, on leaves which remain entire on account of the inability of the males to pierce them. The length of life of a large number of males isolated by themselves on leaves within cheesecloth bags was from two to five days, although a single individual lived seven days. On the other hand, males confined with females under the same conditions lived from four to thirty days, the greater number living considerably longer than five days.

To determine whether this longer period of life was due to feeding or to possible psychological influence or physiological effects following mating, males were isolated upon leaves upon which females had previously been confined and which leaves had been pierced by them. The males were thus afforded an opportunity to feed without being subjected at the same time to possible influences above mentioned, due to the presence of the females. Again, in order that they might have a condition approximating to that when free and at large upon the plants in the greenhouse — leaves with both old and new scabs — each series of males and females was alternated between the leaves, upon which they were respectively isolated at frequent intervals. Of the 19 males kept under these conditions only 3 lived considerably longer (eleven, twelve and thirteen days, respectively) than those kept by themselves on the unpunctured leaves.

On the other hand, of the 43 males confined with females of various ages in glass jars in absence of all food, the females being replaced daily or every other day, and mating observed in many instances, the usual longevity (if a single individual which lived four days is excepted) was three days.

Oviposition.

The details of the egg-laying process are practically a repetition of those of the feeding process. It differs from the latter process only in one essential particular, viz., the deposition of a single egg in the horizontal incision, in immediate contact with the epidermis of the leaf, just before the ovipositor is withdrawn. The tissue in contact with the epidermis having been sufficiently cut or macerated, the ovipositor is partially retracted for a few seconds, then protruded for a final and last time (often twice), the egg being deposited at the same time. The time spent in piercing and cutting the tissue in oviposition, in the instances observed by the writer, varied from twenty to forty-five seconds, and the subsequent feeding, from five to thirty-eight seconds. Only in a single instance did a female fail to feed after the deposition of the egg. The eggs are, as a rule, deposited from the lower surface of the leaf, and can be seen through the epidermis with the aid of a hand lens when the light is favorable. As a rule, the young leaves at the apex of a branch, or shoot, are not oviposited in, although they may be pierced for feeding purposes. The latter part of the afternoon appears to be a favorite time for oviposition.

Dr. Britton (Eleventh Report of the State Entomologist of Connecticut, 1911, p. 342) states that "the eggs are laid in or on the underside of the leaves." The writer has found only one egg deposited on the surface (lower surface) of the leaf during his investigations, and he regards the phenomenon as abnormal, as the larva, as will be seen below, is unable to rupture the epidermis of the leaf and start a mine, and, when exposed on the surface of the leaf by being taken out of the mine, or by rupturing the epidermis which shields it, soon perishes.

Oviposition in Artificial Light.

While engaged in making an observation one evening on some adults confined upon a leaf within a cheesecloth bag on a plant in the laboratory, the writer noticed a female in the act of piercing the epidermis of the leaf. Whether this was done for the purpose of merely feeding, or for ovipositing, he was unable to say. To determine whether fertilized females would oviposit in artificial light, two fertilized females were isolated in the evening on a leaf within a cheesecloth bag on a plant placed in a darkened room. The leaf on which these females were confined was exposed to a fairly strong light, being about 15 inches from a 32 candle-power Mazda lamp. At this distance the leaf seemed to be — as perceived by the palm of the hand — just out of the higher temperature zone formed by the radiation of the lamp. Also, the leaf was so placed as to receive a uniform amount of light on its two surfaces.

The flies were removed from the leaf early next morning, having been on it for a period of ten hours. On examination it was found that oviposition had taken place. Twenty-four larvæ were subsequently counted.

Oviposition in Absence of Light or Total Darkness.

In this case five females that were caught at large on plants in the insectary in the forenoon (four of these were taken as they disengaged from mating) were isolated in the evening on a leaf within a cheesecloth bag on a plant placed in a dark room. In addition, the portion of the plant bearing that leaf was covered with a black cloth bag impervious to light. The flies were removed early next morning, after being on the leaf for nearly eleven hours. On examination, eggs were found to have been deposited. Eight larvæ hatched.

Assuming that the number of larvæ hatched in this experiment, as well as in the preceding one, represents the number of eggs laid in each, it is at once apparent that the number of eggs laid per female by the five females in absence of light was much smaller than the number laid per female by the two females in artificial light, the proportion being 1.6:12. Also, it should be borne in mind, that as the five females were taken in the morning and were not placed on the leaf until evening, they had neither the opportunity to feed nor to oviposit for a period of about ten hours previous to being placed on the leaf. These facts, in conjunction with their usual inactivity in darkness under normal conditions, leads the writer to believe that under normal and natural conditions oviposition in absence of light does not take place, and that the few eggs laid by the females in the experiment were due in all probability to the abnormal conditions to which these females were subjected previous to their isolation on the leaf.

Again, it is possible that some of the eggs were deposited while the flies were being placed on the leaf by artificial light, although it was endeavored to keep them from doing so by keeping the leaf in constant agitation. At any rate, all the eggs could not have been deposited within that short time.

However, the fact remains that absence of light or total darkness is not necessarily an absolute bar to oviposition.

Oviposition — how soon after Emergence.

To determine how soon after emergence egg-laying begins, virgin females soon after their emergence were confined with males until they mated. Immediately following mating, each female was isolated on leaves on a plant in the laboratory, being shifted from leaf to leaf at regular and short intervals. One of these females laid her first eggs (fertile eggs) between twenty-five and thirty-six hours after emergence and between seventeen and twenty-eight hours after fertilization; another between thirty-one and forty-three hours after emergence and between two and three hours after fertilization; another between thirty-one and thirty-six hours after emergence and between twenty-two and twenty-five hours after fertilization. The rather wide limits are due to the limits of the period during which each female emerged, and which necessarily has to be embraced. It would seem, then, if these three females can be taken as criteria, that the first eggs are deposited on the second day of adult life or the second day after emergence, in the laboratory, at least.

Length of Egg-laying Period.

To learn how long females continue ovipositing, newly emerged virgin females were confined with males within cheesecloth bags on leaves on plants in the laboratory. New males were introduced from time to time to take the place of those dying, the females never being without males for any great length of time. These flies were shifted periodically, daily, or every other day, from one leaf to another, throughout the lifetime of the females. After the flies were removed the leaves were examined with a pocket lens, but the presence of larvæ within the leaves was surest proof that eggs were deposited.

One female, in March and April, which lived for twenty-one days, continued ovipositing to within three days of her death, the last eggs being deposited on the eighteenth day. Another female, in March, which also lived twenty-one days, continued to oviposit to within six days of her death, depositing the last eggs on the fifteenth day. Another one, also in March, which was confined with males upon a plant in a cage in the insectary for the purpose of ascertaining the number of eggs a female deposits during her lifetime, oviposited for the last time, as closely as could be calculated, on the sixteenth day of her adult life. Just when this female died is not known. Still another female, in May (latter part), which lived seventeen days, continued ovipositing to within one day of her death, depositing the last eggs on the sixteenth day.

Number of Eggs laid by a Female.

The above experiments for the determination of the length of the egg-laying period were used also as a means for ascertaining the number of eggs laid by a female during her lifetime.

As the marguerite leaves on which the flies were confined were not very large, and as a large number of eggs was laid during some of the periods during which each female was kept on a single leaf, it was not possible to count with any degree of accuracy the number of eggs laid during that period. Instead of the eggs, therefore, the larvæ were counted. The newly hatched larva, just as soon as it was recorded, was killed by being stabbed with a needle. It was thus prevented from obscuring and masking other larvæ by its mining. In this way, also, the possibility of its being counted more than once was obviated. But even with these precautions — owing to their escaping death — quite a number had to be denominated as doubtful.

The female, in March, which oviposited for sixteen days out of twenty-one which constituted her adult life, produced 141 larvæ. If 28 are subtracted from this number as having possibly been counted twice, she produced only 113. As this female was shifted from leaf to leaf daily, there is a record of the number of eggs laid every day during the entire period. The distribution was as follows: —

$$1-\overset{2}{10}-\overset{1}{3}-\overset{2}{12}-\overset{1}{8}-\overset{9}{16}-\overset{3}{6}-\overset{5}{14}-\overset{1}{11}-6-\overset{2}{8}-7-4-\overset{2}{4}-2-1=\frac{28}{113}$$

The upper series of figures represents the doubtful ones.

From this record it is seen that on the first day of the egg-laying period only one egg was deposited, and that similarly only one was laid on the last day; that the greatest number for a single day was deposited the sixth day; that there was in a general way a gradual decrease from the eleventh day to the last; that about two-thirds of the entire number were deposited during the first half of the period. Another interesting feature is seen in the alternation in the relative number of eggs laid, or the rise and fall of the numbers laid, from day to day, during the first half of the period.

The female, in March and April, which oviposited for eighteen days out of the twenty-one which constituted her adult life, produced 136 larvæ, but 16 must be counted as doubtful. This number, however, does not represent the total number, as the leaves on which the female was kept from the twelfth day to the seventeenth, inclusive, were accidentally detached from the plant and were lost as far as results were concerned. A daily record is not available in this case.

The female, during the latter part of May, which oviposited for fifteen days out of the seventeen which constituted her adult life, produced 25 larvæ, 5 of which are doubtful, and deposited 76 eggs, larvæ and eggs together totaling from 76 to 81. The eggs deposited after the third day of the oviposition period failed to hatch for some reason. As it was rather difficult to make out the eggs on this particular plant, and made more difficult some days because of poor light, the number of eggs counted in all probability falls short of the actual number laid. The daily record was as follows: —

$$5-\overset{1}{19}-\overset{4}{16}-4-1-4-5-5-1-2-1-1-6-3-3=\overset{5}{76}$$

As in the first case, the upper figures represent the doubtful ones.

This female deposited the greatest number of eggs for a single day the second or third day, and she deposited at least half of the total during the first three days of the oviposition period. In this case, as in the first, the great bulk of the eggs was laid during the first half of the period.

In other cases newly emerged virgin females were confined with males in cylinder jars until they coupled. As soon as they separated, they were isolated on plants, one female on a plant, in cages in the insectary. New males were introduced from time to time to insure fertilization. Of the three females thus confined, however, only one was successfully carried through a complete egg-laying period. In this case the pupæ produced were counted, as it was impossible to count either the eggs or larvæ without allowing the female to escape; the number counted was 132.

Length of Adult Life.

In these experiments, as in some of the others, cheesecloth bags were again made use of, males and females together, and females by themselves, being confined within the bags upon leaves on plants in the laboratory. In all cases, except one in which a male lived as long as a female, the females lived longer than the males, the length of life of the males ranging from four to thirty days, while that of the females ranged from eleven to forty-seven days. In a number of cases the segregated females lived much longer than those confined with males, their length of adult life ranging from eleven to sixty-seven days.

Whether the phenomenon of the longer life of some of the females kept by themselves was merely a coincidence, or whether it was due to their not having the opportunity to mate, the writer is unable to say, in absence of more extensive data.

In absence of food, the greatest longevity — the usual (a single individual lived four days) — was three days.

THE EGG. (PLATES I. AND II., FIGS. 3, 5.)

The egg is colorless, somewhat cloudy; smooth; elongate oval, though rarely oval, somewhat broader towards one or the other end, more often towards the posterior, and, as a rule, more bluntly rounded at the anterior end; a compound microscope reveals a gelatinous cap at the anterior end, over the micropyle. It is somewhat variable in size: a number of measurements taken showed a length of .25 to .33 millimeter and a width of .14 to .17 millimeter. Its length is, as a rule, slightly more than twice its width.

The segmented embryo is easily made out under the compound microscope in an egg somewhat advanced in its period of incubation. In a still older egg the embryo is found to be already provided with its dark chitinous rake or rasping organ, the dark color of which contrasts strongly with the general paleness of the rest of the body. Another feature of such an embryo is its restlessness. Shortly before hatching this restlessness or activity is strongly marked.

Length of Egg Stage.

The period of incubation is dependent upon the temperature at which the eggs are incubated. To determine the length of this period eggs were marked at the time of their deposition within leaves of plants in the insectary, and these were then periodically examined for their hatching. In other instances, egg-laying females were confined within cheesecloth bags for short periods, upon leaves on plants kept in the insectary, and on others kept in the laboratory, and the eggs deposited in them were then examined from time to time, as in the above cases, for their hatching. The eggs incubated in the laboratory, where the temperature was higher, hatched in from two and one-half to three days after they were deposited. In the insectary, however, where the temperature approximated more or less to that at which marguerites are kept, — about 55° at night and about 65° to 70° during the day (it fell somewhat below and rose somewhat above this both at night and during the day),— they hatched in from a little over four and one-half to somewhat over five and one-half days. The great majority, however, hatched in from nearly five to somewhat over five and one-half days. The greater variation in the length of the period in the insectary was probably due to the greater variation in the temperature, — a condition which could not very well be avoided. There is a record of a period of six and one-half days in the case of two eggs. The writer, however, cannot vouch for its correctness. The larva begins feeding immediately after hatching.

THE LARVA. (PLATES I. AND II., FIGS. 4, 6.)

The larva or maggot mining within the leaves is colorless, the greenish-yellow cast which marks the posterior half being imparted by the green and black pellets of leaf tissue or food which in chain or strand like formations are visible through the body wall. In form it is subcylindrical, tapering anteriorly and posteriorly from the region of the fifth and sixth segments, terminating subacutely anteriorly, and truncately posteriorly. When fully developed it measures about 3.5 millimeters in length and .75 millimeter to slightly over in width across its stoutest portion. It is composed of twelve segments. The first segment is very small and appears like a papilla of the much larger second segment, and contains, ventrally, the mouth opening; segments three and four are comparatively short; the five terminal segments are distinctly longer than the five segments immediately anterior to them. Two contiguous subcylindrical caudal spiracles, dark terminally, project backward from the dorsal portion of the apical end of the last segment. These spiracles are connected by sinews and branched, longitudinal, dorso-lateral, tracheal trunks, one on each side of the body, with the two contiguous cephalic spiracles situated dorsally on the posterior portion of the second segment, each caudal spiracle being connected with the cephalic spiracle on its own side. The anal opening is located at the posterior end of the terminal segment, on the ventral aspect. At the anterior end is seen the dark-colored chitinous and forked oral appendage or rasping organ, conspicuous for its dark color.

The rasping organ or rake is composed of two similar halves lying side by side. They are joined at some points in their course, and the interval between them at other points is so small that it is difficult to make them out at those points as distinct pieces. Each half consists of a short, stout anterior piece or head, the anterior margin of which is modified into strong teeth, and of a more slender and elongate posteriorly forked framework to which the toothed head is attached. The upper of the two posterior prongs is somewhat arched and is longer than the straight lower one. The two halves are joined for a short distance in the vicinity of the heads and at the posterior portions of the lower prongs. The heads are but slightly separated. The whole works as a unit.

In the mine the larva lies on one side, moving along by bodily or muscular contractions aided very likely by its rasping organ, — which can be seen with the aid of a lens, swinging quite rapidly in a dorso-ventral plane, — with which it can grasp and attach itself to the leaf tissue. Taken out of the mine, or uncovered within the mine by rupturing the overlying epidermis, it is practically helpless. It seems unable to pierce the epidermis of the leaf and start a new mine, nor does it know how to continue feeding in the opened mine. Feeding is, as a rule, attempted, but the attempts are feeble. Thus exposed, it remains active for some time, but its helplessness in this new environment is plainly apparent; its various motions bespeak but a helpless despair. The bulk of its energy soon spent, its activities gradually lessen and finally cease, death resulting in a few hours — the time depending upon the conditions to which it is exposed — from a loss of bodily moisture. In water it continues to live for a much longer period — one lived for slightly over twenty-four hours.

As will be recalled, the eggs are as a rule placed from the lower surface, immediately above the epidermis. The larvæ on hatching, however, do not remain feeding on the spongy parenchyma. With a few exceptions they soon make their way to the palisade parenchyma immediately below the epidermis of the upper surface, where they continue for the remainder of their larval existence, going down again, as a rule, only when the supply of food in their course has been previously exhausted by a brother miner, or to pupate. They make their way to the palisade parenchyma either by mining over the edge of the leaf or by boring directly through the central portion of the mesophyl. Rarely the newly hatched larva will bore its way through in this fashion almost immediately, leaving no trace of its existence whatsoever on the lower surface.

The writer's curiosity was early aroused by this habit of the larva. Of a number of reasons which at first suggested themselves to account for it, only two were finally retained as being the more likely, viz., light and food. The question to be answered, then, was: Is the larva attracted to the palisade parenchyma because of the more and greater degree of light which that surface received, or because of the better food conditions which the palisade parenchyma affords? As regards the latter part of the question, it is well known that the palisade cells composing the palisade parenchyma are compact or close together, while the cells comprising the spongy parenchyma are separated by comparatively large interspaces.

To determine whether light or food was the influencing factor, a number of simple experiments were undertaken. In one series, the upper surface of leaves which were infested by newly hatched larvæ, which larvæ had not as yet made their way to the palisade parenchyma, were darkened by being painted over with India ink.

To guard against inconclusiveness of the first series, owing to the possibility of the ink penetrating and proving repellent, another series of similarly infested leaves were covered with black paper impervious to light. In other cases similarly infested leaves were so fixed as to cause them to remain in an upright position so that both surfaces received an equal amount of light. In still other instances such leaves were so fixed as to reverse their surfaces, the true lower surfaces being turned up towards the better light, the true upper surfaces being turned so as to receive less light. In a few other cases areas directly in the course of larvæ which were already mining in the palisade parenchyma were darkened for the purpose of determining the behavior of the larvæ when the darkened areas were reached.

As a result of the above experiments it may be said that the influencing factor is food supply. Light, however, did appear to be somewhat of an influencing factor in some instances in the case of young larvæ.

The mining (Fig. 10) as it appears on the surface of the leaves shows no particular design. It appears as straight or irregular lines running transversely or diagonally, but usually in a longitudinal direction, and often in loops. This condition is still further complicated in leaves which are infested by more than one larva. In such cases the mining may be seen in patches, or, as it very often happens, the entire leaf is mined. A favorite course for mining is along the margin of the leaf. Within the mine the course of the larva may be traced by a chain of black pellets of excreta which it leaves in its wake.

The mines, or better, perhaps, the channels, are as a rule within the palisade parenchyma, but they dip down now and then into the spongy parenchyma, and, as it often happens, a large portion of a mine may be wholly in the spongy parenchyma immediately above the epidermis of the lower surface. Often, when the food supply is limited, owing to the size of the leaf, or when there are a number of larvæ within one leaf, the entire mesophyl or fleshy portion of the leaf is devoured.

Length of Larval Life.

The length of the larval period, like that of the egg, varies with the temperature to which it is subjected, and is in all probability modified in addition by the relative abundance of food. Of the number of larvæ kept under observation from the day of their hatching, 122 were successfully followed to the day of their pupation, and are available. Sixty-one, or one-half the total number, were mining in plants which were kept in the insectary and were subjected to a temperature similar to that to which the eggs were subjected. The remaining 61 were subjected to a temperature which was, on the whole, much higher (unfortunately the exact temperature is not available) than that to which the first lot was subjected, the plants which they were infesting being kept in a room adjoining the insectary. Again, those in the insectary were followed during November, and the plants in which they were feeding were inclosed within cheesecloth bags to avoid further infestation. The second lot, on the other hand, were followed during February; and as the plants in which they were feeding were kept in a room which was free of adult flies, they were not covered. In both series the killing of larvæ other than those which were being followed had to be resorted to from time to time in order not to lose track of the others.

TABLE I. — *Length of Larval Life of 61 Larvæ in the Insectary during November, at a Temperature of about 55° at Night and of about 65° to 70° during the Day. (See Temperature in Connection with Length of Egg Stage.)*

NUMBER OF LARVÆ.	Length of Life (Days).	NUMBER OF LARVÆ.	Length of Life (Days).
7,	11	5,	14½
4,	11½	4,	15
9,	12	1,	15½
3,	12½	3,	16
9,	13	2,	16½
5,	13½	1,	17
7,	14	1,	18

It is thus seen that there is quite a variation in the period of growth or development of the larvæ, independently of temperature. Food supply probably accounts for some of this variation.

TABLE II. — *Length of Life of 61 Larvæ in the Room adjoining the Insectary during February, at a Temperature, on the Whole, much Higher than that during November.*

NUMBER OF LARVÆ.	Length of Life (Days).	NUMBER OF LARVÆ.	Length of Life (Days).
11, ...	6	4, ...	9
23, ...	7	1, ...	9½
4, ...	7½	2, ...	10
8, ...	8	2, ...	11
6, ...	8½		

A comparison of the two tables will show at once the difference in the lengths of the larval periods of the larvæ of the two lots, due to difference in temperature. It should be noted also that there was almost as great a range of variation in the development of the individuals of this lot as in that of the first.

PUPARIUM AND PUPA. (PLATES II. AND III., FIGS. 7, 8, 11.)

Pupation takes place within the larval mine and inside the last larval skin, the latter thus becoming a puparium. The larva when full grown merely shortens up and becomes inactive. Before becoming inactive, however, it deepens slightly that portion of the mine in which it is to come to rest, forming a more comfortable bed or resting place for itself, as one might say. Having done this, it turns upon its dorsal surface and gradually assumes a state of inactivity, becoming yellowish-white opaque at the same time.

The puparium, at first of the color of the contracting maggot or larva, — pale yellow, — becomes in time dull pale yellow or straw color, or it turns to reddish brown, brown and dark brown, darkening with age. It is easily perceived by the unaided eye through the pale, semitransparent epidermis on either surface of the leaf (Fig. 11). Normally it is completely covered by the epidermis, only the minute cephalic spiracles at the extreme anterior end projecting. The caudal or anal spiracles are completely covered, and are not visible on the surface. Dr. Lintner must have mistaken the cephalic spiracles for the anal, in stating that the latter are "thrust outward" through the epidermis. (Fourth Report on the Injurious and Other Insects of the State of New York, 1888, pp. 74, 75.)

The apparent displacement of the cephalic spiracles (see larva) is brought about by the contraction of the anteriormost ventral larval segments before the larva becomes inactive, drawing along with it, first upward then analward, the anterior dorsal portion of the body. As a consequence, the cephalic spiracles, which in the larva are situated on the posterior portion of the second dorsal segment, assume an anterior ventral position in the puparium.

In shape the puparium may be said to be scaphiform or boat-shaped. In outline it is long oval, and approximates in a general way towards that of the larva, being broadest anterior to the center, and tapering from its stoutest portion anteriorly and posteriorly, terminating acutely anteriorly and somewhat truncately posteriorly. As a rule, the length is twice the width (width across the stoutest portion), although not infrequently the width exceeds half the length. A large number of measurements showed a length of 2.25 to 3 millimeters and a width of 1 millimeter to 1.5 millimeters. The greatest width does not necessarily go with the greatest length. The segments are quite strongly marked, and the spiracles are prominent.

While the puparia are seen through the epidermis (Fig. 11) on either surface of the leaf, by far the greater number occur near the lower surface, the proportion being about 2:1; that is to say, pupation takes place more often immediately above the epidermis of the lower surface of the leaf than immediately below the epidermis of the upper surface, the larvæ when about full grown making their way towards the lower surface for that purpose by eating their way through the central portion of the mesophyl. The mining is continued, as a rule, for a greater or lesser distance, after they have eaten their way through.

The puparial content, at first a semiliquid, whitish mass which clings to the wall of the puparium, gradually hardens, through the loss of its fluids, into a white mass distinct from the puparial wall. This mass then gradually differentiates into the pupa proper, which shows the three primary regions — head, thorax and abdomen — of the adult insect, and the rudimentary legs and wings or wing buds. The pupa proper is formed within two and one-half days after pupation at a temperature of about 60° at night and 70° and over during the day, — temperatures slightly higher than those at which marguerites and low-temperature loving plants of its kind are usually kept. It is quite probable that at those lower temperatures the results would be slightly modified. The pupa proper is cream-white in color; the legs are folded on the ventral surface; the wing buds are pressed closely to the sides of the body, their apical portions inclining ventrally.

Length of Pupal Life.

The length of the pupal period, like that of the egg and larva, varies with the temperature, as will be seen by the tables that follow. In all, the periods of 197 are available. One hundred and thirty-four of these developed in plants in the insectary during November, and were subjected to a temperature similar to that to which the eggs and larvæ were subjected. In fact, the greater number of this lot were the pupæ of the larvæ which were followed in the insectary for the purpose of determining the length of the larval period. The remaining 63 developed during the last days of February and the first part of March, and, like their larvæ, in the room adjoining the insectary, where the temperature was markedly higher than in the insectary.

TABLE III. — *Length of the Pupal Period of 134 Pupæ which developed in the Insectary during November, at a Temperature of about 55° at Night and of about 65° to 70° during the Day. (See Temperature in Connection with Length of Egg Stage.)*

NUMBER OF PUPÆ.	Length of Pupal Period (Days).	NUMBER OF PUPÆ.	Length of Pupal Period (Days).
2, ...	12	15, ...	14½
2, ...	12½	20, ...	15
27, ...	13	2, ...	15½
18, ...	13½	1, ...	16
47, ...	14		

It is thus seen that the length of the pupal period also varies independently of the temperature. The variation, however, it should be noted, is less than among the larvæ, as might be expected, especially among the larvæ which, like the pupæ, developed in the insectary, and with which they should more properly be compared. It should also be noted that a period of from thirteen to fifteen days, inclusive, embraces the great majority, indeed, almost all.

TABLE IV. — *Length of the Pupal Period of 63 Pupæ in the Room adjoining the Insectary, during February and March, at a Temperature, on the Whole, much Higher than that in the Insectary during November.*

NUMBER OF PUPÆ.	Length of Pupal Period (Days).	NUMBER OF PUPÆ.	Length of Pupal Period (Days).
7, ...	8	26, ...	10
1, ...	8½	1, ...	10½
19, ...	9	3, ...	11
3, ...	9½	3, ...	12

A comparison of the two tables will show at once the difference in the lengths of the pupal periods of the two lots of pupæ, due to the difference in temperature. Of interest, also, is the fact that the range of variation in the two lots was the same.

The newly emerged perfect female may be described as follows: head, pale yellow, with a broad central longitudinal black band on the occiput; antennæ, black; thorax, grayish; macrochetæ, black; wings, gray, pale at base, unspread; legs, black, with pale-yellow markings on femora and tibiæ; abdomen, pale yellow, dorsally and ventrally, with darker transverse, broad bands, one on each segment; setæ, black; terminal segment, black.

Length of Life Cycle.

The length of a generation varies, owing to the variability of the stages constituting it. The mean or average length of a life cycle, however, may be obtained by combining the mean or average length of each stage.

The average lengths of the periods constituting the life cycle during November, at a temperature at which marguerites are usually kept (see temperature in connection with length of egg stage), are as follows: —

	Days.
Time elapsing between emergence of adult and oviposition,	1½
Length of egg stage,	5
Length of larval stage,	13
Length of pupal stage,	14
Average length of one generation,	33½

Number of Generations in the House.

Knowing the length of a generation, we can calculate the approximate number of overlapping generations or broods which occur in the house from the setting in of the cooler season, when the flies make their first appearance in the house, or when they reappear, or appear in greater numbers, to about Easter, when most of the marguerites are sold out, or to the end of May, in cases where the plants are grown for their bloom. Thus there are at least four complete broods for the period between November 1 and April 1, and at least six complete broods for the period between November 1 and June 1, for a life cycle of thirty-three and one-half days. Owing to the higher temperature during April and May there may be an additional generation, or partial generation, for the period between November 1 and June 1.

Hibernation.

Is the insect able in some one of its stages, say pupa, to pass the winter out of doors? This question is suggested by a letter from Mr. Walker Holden. According to this letter the marguerites and feverfews in Mr. Holden's greenhouse were badly infested by the insect during the winter of 1911. The following spring these plants, as was the practice, were removed from the house to the garden for the summer, and towards fall furnished the cuttings for a new crop. That fall and winter (1911–12), however, there were no signs of the insect in the greenhouse. In the spring the house was again cleared, and the plants, apparently perfectly clean, removed to the garden. In late summer, however, Mr. Holden found the plants infested, and during the following fall and winter (1912–13) the insect was again present in troublesome numbers in his greenhouse.

How is the absence of the fly during the fall of 1911 and winter of 1912 to be accounted for? As there are no other greenhouses in Mr. Holden's vicinity, it could not have passed the winter actively in a neighboring greenhouse. Unless, then, as is possible, it passed the winter in some near-by dwelling house, where some one of its food plants was kept for ornamental purposes, as occasionally happens, hibernation is the only rational explanation that remains.

CONTROL.

Picking of Leaves.

Until recently the picking and destruction of the infested leaves was the only means known for the control of this insect. This method, however, aside from other disadvantages, has not proven effective in all cases. Mr. Walker Holden has had fairly good success with it in the case of white marguerites, but it was utterly ineffective in the case of yellow marguerites, and it rendered the feverfews unsalable. It is quite probable, also, that he would have experienced more difficulty in connection with the white marguerites had he not had in the house at the same time yellow marguerites and feverfews, of which plants the flies are very fond. But aside from the consideration of effectiveness, it is obvious that as a means of control the method is by itself unsatisfactory in cases where plants are grown in quantity and time is valuable. Moreover, the loss of leaves is not to the advantage of the plant.

Spraying.

"Black Leaf 40."

It was the intention of the writer to discover, in connection with his other studies of the pest, a more effective method of control. But before the experiments along these lines were begun, a note entitled "A Remedy for Chrysanthemum Leaf Miner," in the "Journal of Economic Entomology" for December, 1912, by J. G. Sanders of the College of Agriculture, Madison, Wis., came to his notice. In this note Mr. Sanders says in part, as follows: —

> While experimenting with contact insectides for their control, the nicotine solutions, especially "Black Leaf 40," used as a spray with or without whale-oil soap solution, proved a complete and satisfactory control. One part of nicotine in 400 parts of water killed the eggs and larvæ readily, as well as the newly formed pupæ. The pupæ of all ages were killed with $\frac{1}{200}$ nicotine solution.

Mr. Sanders having discovered an effective remedy, the writer thought it superfluous to experiment further along original lines; nor, again, did the time available make it convenient for him to do so. His own experiments, therefore, were designed merely to test Mr. Sanders's results. A solution of 1 part of "Black Leaf 40" in 400 parts of water killed the eggs and the larvæ readily, as Mr. Sanders has pointed out, and a large proportion of the newly formed pupæ. A solution of 1 part of "Black Leaf 40" in 200 parts of water killed a large proportion of the older pupæ. The addition of whale-oil soap did not seem to give any better results.

The "Black Leaf 40," which is a concentrated solution of nicotine sulfate, containing 40 per cent. active nicotine, is manufactured by the Kentucky Tobacco Product Company, Louisville, Ky. It is sold in ½, 2½ and 10½ pound cans, and may be obtained direct from the manufacturers, if it cannot be obtained from a near-by dealer.

"Nico-Fume" Liquid.

Mr. W. R. Nicholson of Framingham was referred to the writer, by Prof. E. A. White of the Department of Floriculture, as one who in all probability was in a position to furnish information regarding the pest. The writer took the opportunity soon after to consult Mr. Nicholson. According to Mr. Nicholson, who grows marguerites on a large scale, the insect was very troublesome in his houses a few years ago. While experimenting with various methods and materials in an effort to control it he tried "Nico-Fume" Liquid as a spray, and found it effective. He has experienced little or no trouble from the insect since he has been systematically using this liquid.

Mr. Nicholson dilutes the "Nico-Fume" in water from about 430 to 450 times, using a cupful — a cup which the manufacturers provide — to 3 gallons of water, and sprays regularly once a week. He begins spraying even before there are any indications of the presence of the insect, preferring to get the start on them rather than have the insect get the start on him. He sprays not only against the Marguerite Leaf Miner with the material at this strength but also, his other plants as well, against aphids. In fact, he is using it as general spray more against aphids and other soft-bodied insects than against the Marguerite Miner, which is of little or no consequence in his houses now. Mr. Nicholson has found no occasion to add soap to the solution.

"Nico-Fume" Liquid, like "Black Leaf 40," is a nicotine solution containing 40 per cent. active nicotine, and is prepared by the same manufacturers. It may also be obtained in the same way. It is sold in ¼ pint, pint, ½ gallon, and gallon cans.

"Nicoticide."

Mr. Nicholson has also used "Nicoticide" at the same strength and in the same way as the "Nico-Fume" Liquid, with equally good results.

"Nicoticide," like the "Black Leaf 40" and the "Nico-Fume" Liquid, is a nicotine solution. It is manufactured by the P. F. Palethrope Company, Owensboro, Ky. It may be had in ounce, ½ pint, pint, and gallon cans.

Relative Cost of the Spraying Materials.

An absolute comparison of the prices of the three spraying materials is not possible for the reason that they are not all sold in similar quantities. A fairly good idea of the relative cost of the "Nico-Fume" Liquid and the "Black Leaf 40," however, may be had from the figures which follow, which indicate the cost per ounce of these materials in each of the quantities in which they are on the market.

"Black Leaf 40."

One ounce in ½ pound costs 10.62 cents.
One ounce in 2½ pounds costs 8.12 cents.
One ounce in 10½ pounds costs 7.44 cents.

"Nico-Fume" *Liquid.*

One ounce in ½ pint costs 11.76 cents.
One ounce in 1 pint costs 8.82 cents.
One ounce in ½ gallon costs 8.08 cents.
One ounce in 1 gallon costs 7.72 cents.

It is thus seen that, on the whole, the "Black Leaf 40" is slightly cheaper per ounce than the "Nico-Fume" Liquid. The "Nico-Fume" Liquid, however, possesses a possible advantage in that it may possibly be used at a slightly lower strength, Mr. Nicholson using it at the rate of 1 part to about from 430 to 450 parts of water, while from his own experiments with "Black Leaf 40" the writer prefers a $\frac{1}{400}$ solution of the latter to that of a $\frac{1}{450}$ solution. It is quite probable, however, that where spraying will be practiced regularly, as is Mr. Nicholson's practice, the "Black Leaf 40," used at the same strength as the "Nico-Fume" Liquid, may prove just as efficient as the "Nico-Fume."

The tables also show very clearly the advantage of buying either material in the larger quantities.

"Nicoticide" as a spray is entirely too expensive as compared with "Black Leaf 40" and "Nico-Fume" Liquid. It costs $1 more per pint, $3 more per ½ gallon, and $4.50 more per gallon than the "Nico-Fume" Liquid, and one pays 17.5 cents per ounce when buying it in ¼ of a pound quantities.

Conclusions and Recommendations.

It is the opinion of the writer that in a general way the method of combating the Marguerite Miner followed by Mr. Nicholson (see "Nico-Fume" Liquid) might be used by others, certainly by large growers of marguerites and those other plants which the insect attacks. The method has proved itself both effective and economical in the hands of a practical and successful florist, and it has stood the test for several years. However, if one has never been troubled by this insect, and if his practice is to fumigate rather than spray against aphids, spraying should begin with the first signs of the operations of the insect. The second application may well follow one week later, as it is highly desirable that the insect be checked to as great a degree as possible at its very start. The spraying should then be continued regularly every eleven or twelve days. A longer interval than twelve days is not advisable, as it is more difficult to kill nearly full-grown or full-grown larvæ, and pupæ are still more difficult. In spring, when it becomes warmer in the house, — or at any time if the plants are grown at a higher temperature than usual, — the sprayings will probably have to come a little more often. Should one succeed in exterminating the insect, spraying might be discontinued after cold weather has set in, for then the danger of the insect's coming into the house is past. With the coming of spring, however, one's vigilance should be renewed, for if the insect is able to pass the winter outside of the greenhouse in a dormant state, that is, to hibernate, there is a possibility, it may get into the house when it becomes active again. If "Black Leaf 40" instead of "Nico-Fume" Liquid is used, it should, at first at least, be used at the $\frac{1}{400}$ strength. Later, especially if one should spray regularly, 1 part to about from 430 to 450 parts of water, at which strength Mr. Nicholson uses the "Nico-Fume" Liquid, might very likely prove effective.

The importance of thorough spraying cannot be overemphasized, as the insect multiplies very rapidly under normal conditions. Both surfaces of the leaf should be entirely and uniformly covered, as the eggs, larvæ and pupæ may occur in any part of the leaf. Special pains should be taken to hit the lower surfaces of the leaves, as from the lower surfaces will be reached the majority of the eggs and newly hatched larvæ — which will thus be cut off at the very beginning of their career of mischief — and full-grown larvæ and therefore pupæ. As the solution must penetrate into the tissues to do its work, it is important also that it adhere well to the leaves. A nozzle giving a fine spray should therefore be used. Should difficulty for some reason or other be experienced in this respect, the addition of soap might be advisable, — whale-oil soap or good laundry soap, at the rate of 1 pound to about 30 gallons of water. The soap increases the adhesiveness of the spray solution through its own adhesive character, and by lessening the formation of drops the last property insures a more even and uniform distribution of the solution on the leaf surface as well.

The soap should be dissolved in water before the "Black Leaf 40" or "Nico-Fume" Liquid is added — the soap cut in thin slices will easily dissolve in some boiling water. After adding, the solution should be stirred thoroughly to obtain uniformity. More material than is needed for one application should not be prepared; in other words, the materials should be mixed shortly before applying.

Natural Enemies.

Spiders.

The various spiders occurring in the greenhouse, by preying upon the adult flies, capturing them directly, and indirectly by enmeshing them in their webs, are of aid to the florist in that they reduce the numbers of the flies. Especially serviceable seems to be *Salticus senicus* Clerk (identified by Mr. J. H. Emerton of Boston), a gray, brownish, and white form, about one-fourth of an inch long, common in and outside of houses all over North America. The front of its head around and above the eyes is white; there is a white band across the anterior end of the abdomen, and two or three oblique white bands on the sides. In some cases a longitudinal white band passes down the middle of the abdomen. This spider is a plant crawler, and the writer has observed individuals again and again on the marguerite plants, preying upon the adult flies.

According to Mr. Whiting of the Department of Floriculture this spider is very valuable in greenhouses in general, preying extensively on the various aphids, on the Rose Leaf-roller (*Archips rosaceana* Harris), extracting the larva from out of the rolled leaf, and on other injurious forms.

Insect Parasites.

As far as the writer knows, no definite insect parasite of the Marguerite Fly has as yet been reported. The late Mr. D. W. Coquillett, however, was of the opinion that such a parasite exists. Referring (Insect Life, VII., 1894–95, p. 400) to some marguerite leaves which he received from the greenhouses of Mr. James Read of Irvington, N. Y., Feb. 28, 1890, from which adults of the Marguerite Miner were reared, he adds: —

> Quite a large series of chalcidid flies belonging to the genus *Chrysocharis* were also bred, but as the other members of this genus are almost without exception parasitic upon other chalcidid or Ichneumon flies, it is quite certain that the present specimens did not prey upon the leaf miners. Their presence, however, is indicative of the very important fact that these miners have an enemy to contend with in the form of a small four-winged fly that has thus far escaped detection.

SUMMARY OF RESULTS.

History and Distribution.

The Marguerite Fly, or Chrysanthemum Leaf Miner is, as far as known, a native insect. It was first reported from a greenhouse near Glen Cove, N. Y., in the fall of 1886. It has since been found in many other localities. At the present time it is definitely known to occur in the following States: New Hampshire, Massachusetts, Connecticut, New York, Pennsylvania, Illinois, Wisconsin and Montana. It is doubtless present in other States.

Host Plants.

The food plants of this insect are apparently restricted to the family Compositæ. Of the cultivated plants, marguerites and feverfews seem to be the favorites. It is also known to attack eupatoriums, gazanias, helianthus, cinerarias, tansies, chrysanthemums, goldenrod, ragweed, dandelions, beggar-ticks, wild carrot, the common white or ox-eye daisy, and everlasting, or ladies' tobacco. It is essentially a greenhouse pest.

Injury and Seriousness of the Pest.

The injury is caused by the larvæ or maggots mining within the leaves, and living upon the mesophyl or fleshy portion of the same. The mining is seen on the surfaces of the leaves as irregular, whitish lines or patches, the latter often extending to take in the whole surface, and causes the death of part or the whole leaf. The activity of the larva or maggot results in a serious interference with normal growth, in checking flowering or in the reduction of the number of flowers normally produced, and in a reduction in the size of the flowers. Small plants may be killed in a comparatively short time if exposed continually to attack. The depredations of the insect are often very serious. In many instances the commercial growing of marguerites and other Compositæ have been given up on account of it.

Life History and Habits.

The adult insect is a small, grayish fly, only 2 millimeters, or $\frac{1}{12}$ of an inch, long, with a comparatively broad yellow stripe or band on each side of the abdomen, and may be seen resting, or crawling lazily about, or making its way from plant to plant in a skipping or hopping flight. The female fly, as a rule, lives longer than the male. Females confined with males upon leaves on plants in the laboratory lived as long as a month and a half. One female may lay between 125 and somewhat over 150 eggs during her lifetime. The eggs are laid singly in horizontal incisions made by the ovipositor, between the parenchyma, or flesh, and epidermis, or skin, of the leaf, — principally between the parenchyma and epidermis of the lower surface. Similar incisions are made, but mostly between the parenchyma and epidermis of the upper surface, for purposes of feeding on the juices of the leaf. The eggs hatch in from slightly over four and a half to somewhat over five and a half days. The larvæ do most of their feeding immediately beneath the epidermis of the upper surface of the leaf, owing to the better food conditions afforded by the palisade parenchyma, and may feed as long as seventeen and eighteen days. Pupation takes place within the larval mine, and more often in those immediately above the epidermis of the lower surface of the leaf. The pupa stage lasts, as a rule, from thirteen to fifteen days, inclusive. The mean or average length of a complete life cycle or generation is about thirty-three and one-half days. The lengths of the different stages vary also with the temperature to which they are subjected. The above periods are for a temperature at which marguerites are usually grown. (See temperature in connection with length of egg stage.)

Control.

The insect may be controlled by spraying with the nicotine solutions "Black Leaf 40," "Nico-Fume" Liquid and "Nicoticide," diluted from 400 to 450 times in water, and applied at intervals of eleven or twelve days, or somewhat oftener if the temperature in the greenhouse is higher than that at which marguerites are usually kept. The picking of leaves, it would seem, is in most cases neither adequate nor satisfactory.

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EXPLANATION OF PLATES

PLATE I.

FIG. 1. — Dorsal view of adult female fly. Greatly enlarged.

FIG. 2. — Wing of adult fly. Greatly enlarged. 1–6, veins; cos, costal vein; ant. c. v., anterior cross vein.

FIG. 3. — Egg showing contents and gelatinous cap at anterior end. Greatly enlarged.

FIG. 4. — Side view of the anterior and posterior portions of the larva or maggot. Greatly enlarged. fd. or., feeding organ or rake; sp., spiracle; tr., tracheal trunk.

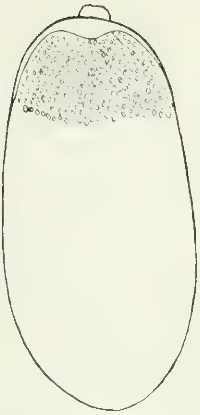
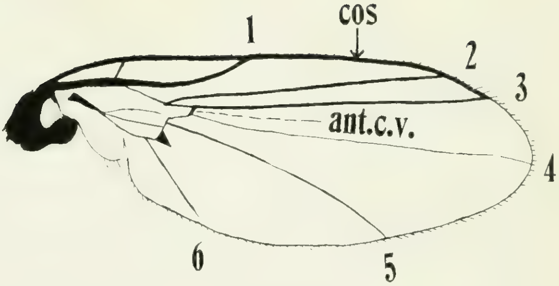


Fig. 3



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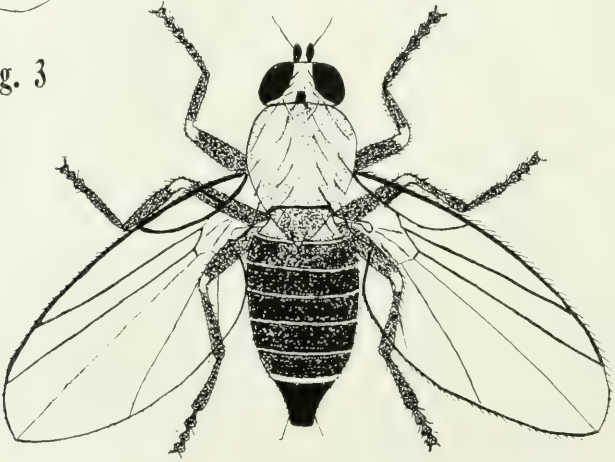

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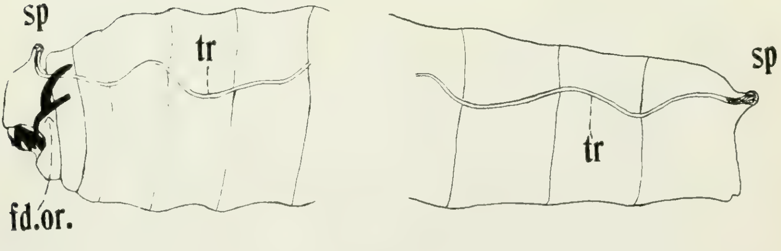

Fig. 4

PLATE II.

FIG. 5. — Egg. Enlarged about twenty-five times.

FIG. 6. — Side view of larva or maggot. Enlarged about nine times.

FIG. 7. — Puparia. Enlarged about twelve and one-half times.

FIG. 8. — Ventral, and latero-ventral view of pupæ. Enlarged about twelve and one-half times.

FIG. 9. — Leaf showing blotches and papillæ produced by the female fly. Enlarged about one and one-half times.

FIG. 10. — Leaf showing the work of the larva or maggot. Natural size.

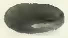

Fig. 5

Fig. 6

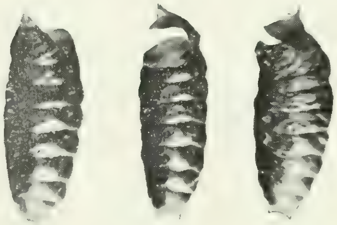

Fig. 7

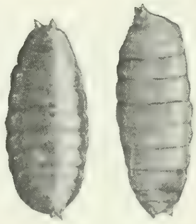

Fig. 8

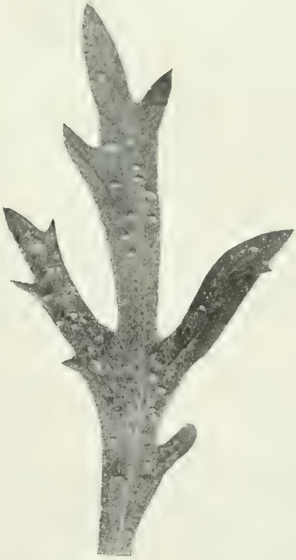

Fig. 9

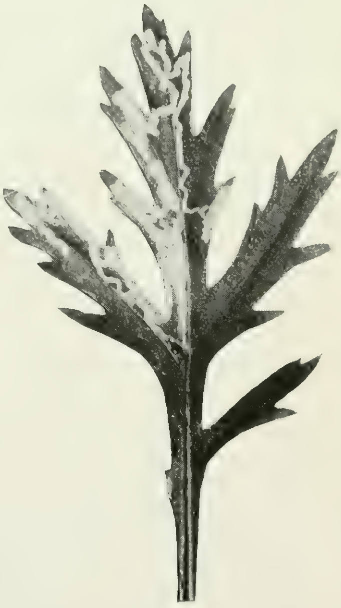

Fig. 10

PLATE III.

Fig. 11. — Leaf with pupæ beneath epidermis. Enlarged about three times.

Fig. 12. — A white marguerite plant badly attacked; the dried-up leaves clinging to the plant.

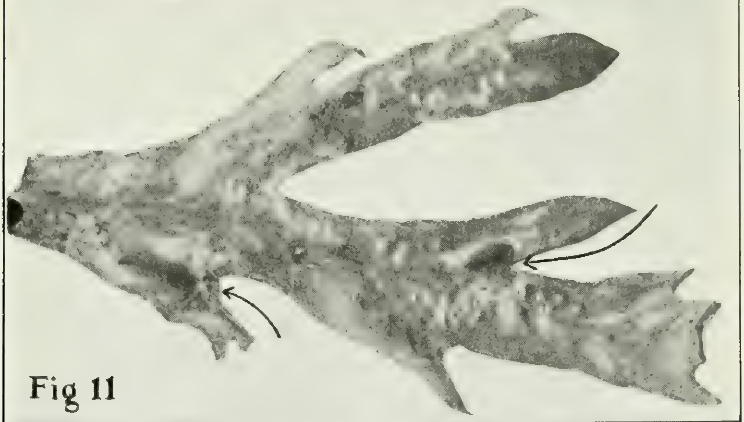

Fig 11

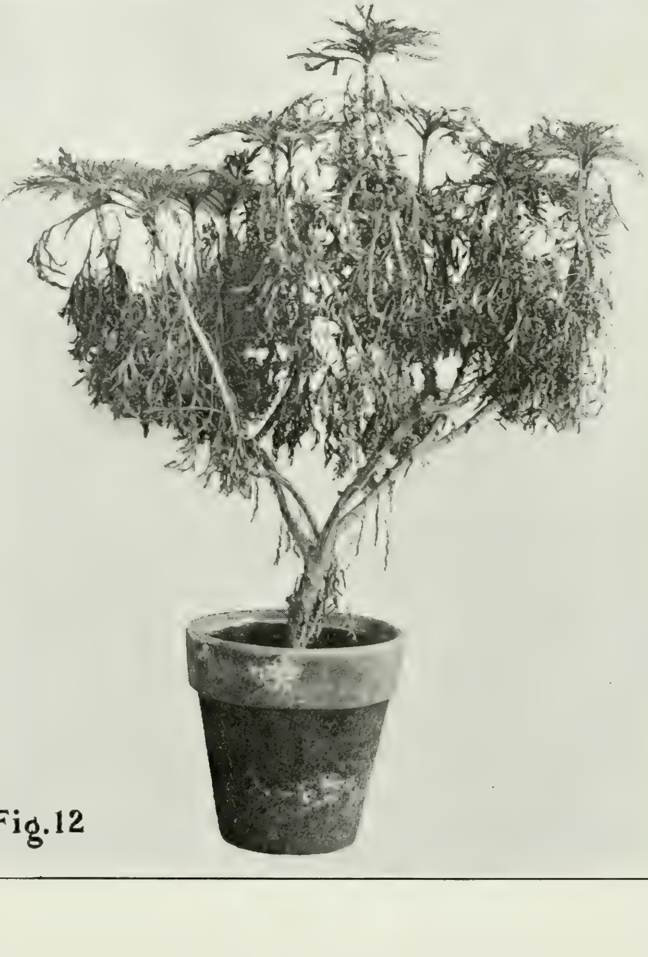

Fig. 12

BULLETIN No. 158 DECEMBER, 1914

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

THE COMPOSITION, DIGESTIBILITY AND FEEDING VALUE

OF

Molassine Meal, Cottonseed Meal and Hulls, Cocoa Shells, Grain Screenings, Flax Shives, Mellen's Food Refuse, and Postum Cereal Residue (CXX Feed)

By J. B. LINDSEY and P. H. SMITH

This bulletin contains a description of experiments conducted to ascertain the feeding value of a manufactured feed which has been extensively advertised, and of a number of by-products from milling and human food industries. It explains of what each material is composed or how it is prepared, states its chemical composition and digestibility, and advises concerning its relative value as compared with a standard cereal or by-product. A statement is likewise made as to the suitability of each article for different classes of farm animals, and the best way to utilize it.

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THE COMPOSITION, DIGESTIBILITY AND FEEDING VALUE OF MOLASSINE MEAL, COTTONSEED MEAL AND HULLS, COCOA SHELLS, GRAIN SCREENINGS, FLAX SHIVES, MELLEN'S FOOD REFUSE, AND POSTUM CEREAL RESIDUE (CXX FEED).

J. B. Lindsey and P. H. Smith.

1. MOLASSINE MEAL.

The Molassine meal offered in Massachusetts is an English product[1] composed of substantially 70 to 75 per cent. of cane or beet molasses and 25 to 30 per cent. of sphagnum moss; the latter, as time passes, decays and forms peat. The moss used in Molassine meal, according to the manufacturers, comes from the upper layers of large peat bogs in Yorkshire, Eng., and is probably more or less humified. It is doubtful if the moss has any particular nutritive properties; hence, the *nutritive value* of the feed consists in the amount of molasses present.[2]

Molassine meal is quite dark in color, rather bulky, somewhat moist and slightly sticky, but is in good merchantable condition and appears to keep well.

(1) *Composition of Molassine Meal.*

Analyses made at the experiment station show it to have the following approximate composition: —

	Per Cent.
Water,	18.43
Ash,	7.52
Crude protein,	9.32
Crude fiber,	6.75
Nitrogen-free extract,	57.51
Fat,	.47
	100.00

---

[1] A product similar to Molassine meal was first made in Germany, where it was patented under the number 79932; it is there known as *Torf-Melasse.* It is also made in France, and known as *Tourbe-Melassée.* Its use in these countries is quite general, particularly as a partial feed for horses.

[2] Kellner and Pfeiffer have shown that peat is without nutritive value.

The presence of so much ash is due to the relatively large amount of molasses. The crude protein is largely in the amino form, and is of doubtful value for flesh and milk production; the extract matter is composed largely of sugar and allied substances; the crude fat or ether extract is of no particular account. A test for potash showed the presence of 4.50 per cent., about the same amount as found in cane molasses.

(2) *Digestibility of Molassine Meal.*

Five trials were made with three different sheep, using 600 grams of hay and 200 grams of Molassine meal in two cases, and 550 grams of hay and 200 grams of the meal in one case. This combination was found to give a rather wide nutritive ratio, so two more trials were made, feeding 550 grams of hay, 150 grams of gluten feed and 200 grams of Molassine meal. The results secured with each sheep, and the average, follow: —

Digestion Coefficients for Molassine Meal.

SHEEP.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Nutritive[1] Ratio.
I.,[2]	59.47	65.31	27.19	14.61	71.30	11.34	1: 11.50
V.,[3]	58.54	78.47	58.10	–	70.84	72.13	1: 6.17
V.,[2]	66.60	86.95	32.51	25.00	75.32	–	1: 10.03
VI.,[3]	64.44	87.85	66.33	–	70.91	63.11	1: 6.13
VI.,[2]	60.86	78.83	24.55	–	71.12	–	1: 10.15
Average, . .	61.98	79.48	41.74	–	71.90	–	–
Cane molasses for comparison.	78.30	54.85	33.34	–	88.84	–	–

[1] Total ration. [2] Fed with English hay. [3] Fed with English hay and gluten feed.

The results show that the Molassine meal has about the same degree of total digestibility as wheat bran. The ash has a high, and the extract matter a fair degree of digestibility. The fiber was poorly utilized; in some instances none was digested. Where Molassine meal and hay were fed the digestibility of the crude protein was low, due in part to the relatively small amount of nitrogen in the ration in proportion to the metabolic by-products. Where gluten feed was added to the ration the digestibility of the protein was considerably higher. The Molassine meal is some 20 per cent. less digestible than cane molasses (proportion of 62 to 78), due to the presence of the sphagnum moss. Applying the digestion coefficients to the analysis of Molassine, one secures the following number of pounds of digestible organic matter in 100 pounds, and by multiplying by 20, the amount in 1 ton: —

Composition and Digestibility of Molassine Meal.

	Composition (Pounds in 100).	Percentage digestible.	Pounds digestible in 100.	Pounds digestible in 1 Ton.
Protein,	9.32	41.7	3.89	77.80
Fiber,	6.75	–[1]	–[1]	–[1]
Extract matter,	57.51	71.9	41.35	827.00
Fat,	.47	–[1]	–[1]	–[1]
Total,	–	–	45.24	904.80

[1] Not determined on account of the unsatisfactory coefficients obtained. Its omission, however, makes little difference in the totals.

The Molassine meal, with 18.43 per cent. of water, is shown to contain 905 pounds of digestible organic matter in 1 ton, as against 1,377 pounds in a ton of corn meal with this same amount of water, and against 1,524 pounds in kiln dried corn meal with 11 per cent. of water. In the former case the Molassine meal would have 66 per cent. of the nutritive value of corn meal, or in the latter case 59 per cent. Viewed solely from the standpoint of nutrition it can safely be said that the material is noticeably inferior to corn or to the other cereals.

(3) *Feeding Experiment with Dairy Cows, 1913.*

This experiment was undertaken for the purpose of comparing the relative value and feeding effect of Molassine meal as compared with corn meal; *i.e.*, to note if the animals would eat the Molassine meal readily, and also to observe its effect upon the general condition of the animal and upon the amount of milk produced.

Six cows were fed by the reversal method in periods of three weeks' duration. Hay, wheat bran and cottonseed meal constituted the basal ration, to which were added definite amounts of either Molassine or corn meal.

TABLE I. — *History of the Cows.*

NAME.	Breed.	Age (Years).	Last Calf dropped.	Served.	Milk Yield (Pounds), Beginning of Trial.
Amy,	Pure Jersey,	5	Dec. 21, 1912	Mar. 4, 1913	24
Betty,	Grade Jersey,	8	Oct. 30, 1912	Feb. 11, 1913	21
Samantha II.,	Grade Holstein,	4	Feb. 13, 1913	– –	35
Fancy II.,	Grade Jersey,	5	Sept. 14, 1912	Jan. 28, 1913	21
Cecile,	Pure Jersey,	7	Dec. 18, 1912	Mar. 9, 1913	21
White,	Grade Holstein,	4	Mar. 12, 1913	– –	43

TABLE II. — *Duration of Experiment, 1913.*

DATES.	Corn Meal Ration.	Molassine Meal Ration.
May 2–May 23,	Fancy II., Cecile, White,	Amy, Betty, Samantha II.
June 6–June 27,	Amy, Betty, Samantha II.,	Fancy II., Cecile,[1] White.

[1] June 13 to July 4 for Cecile.

Twenty-two days elapsed between the two parts of the experiment in case of Cecile, as she could not be induced to eat the full ration of Molassine (4 pounds), and it was finally found necessary to reduce the amount to 3 pounds and add 1 pound of corn meal. The intermediate period for the other cows was fourteen days.

Care and Feeding of Animals. — They were kept in roomy stalls, carded daily and turned into a protected barnyard during each pleasant day. They were fed twice daily; the hay was given some time before milking in the afternoon, and the grain just before milking, while in the morning the grain was given just before and the hay just after milking. Water was supplied constantly by aid of a self-watering device.

Character and Cost of Feeds. — The hay was an admixture of timothy, red top and some clover. Unfortunately, it varied in texture, and during part of the experiment it was rather coarse, which caused the animals to leave small amounts on different days. The bran was of the spring variety. The cottonseed meal was of fair quality, containing about 39 per cent. of protein. The corn meal was local-ground and of good quality. The Molassine meal has already been described. The market price of the several feeds at the time of the experiment was as follows: —

	Per Ton.
Hay,	$23 00
Corn meal,	26 00
Cottonseed meal,	34 00
Wheat bran,	27 00
Molassine meal,	40 00

Weighing the Animals. — Each cow was weighed for three consecutive days at the beginning and end of each half of the trial, before the afternoon feeding.

Sampling Feeds and Milk. — The hay was sampled at the beginning, middle and end of each half of the trial in the usual way, as described in other experiments of this character. The grains were sampled daily, and the samples preserved in glass-stoppered bottles and brought to the laboratory at the end of each half of the trial for dry-matter determinations and complete analyses.

The milk of each cow was sampled daily for five consecutive days for each week of the trial. The usual method of sampling was followed.

TABLE III. — *Analysis of Feedstuffs.*

CHARACTER OF RATION.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Hay,	10.54	9.29	2.22	42.94	28.86	6.15
Bran,	12.13	16.36	4.80	51.46	9.19	6.06
Cottonseed meal,	7.84	39.10	8.51	27.68	10.60	6.27
Corn meal,	14.06	8.87	3.67	70.17	1.98	1.25
Molassine meal,	19.61	9.08	0.41	57.71	6.06	7.13

TABLE IV. — *Total Rations consumed by Each Cow (Pounds).*

Corn Meal Ration.

NAME.	Hay.	Bran.	Cottonseed Meal.	Corn Meal.	Molassine Meal.
Fancy II.,	314	42	21	84	–
Cecile,	328	42	21	84	–
White,	464	63	53	105	–
Amy,	369	42	21	84	–
Betty,	371	42	21	84	–
Samantha II.,	483	63	42	105	–
Totals for herd,	2,329	294	179	546	–

Molassine Meal Ration.

NAME.	Hay.	Bran.	Cottonseed Meal.	Corn Meal.	Molassine Meal.
Fancy II.,	330	42	21	–	84
Cecile,	360	42	21	20	63
White,	478	62	51	–	103
Amy,	344	42	21	–	84
Betty,	358	42	21	–	84
Samantha II.,	471	63	42	–	105
Totals for herd,	2,341	293	177	20	523

TABLE V. — *Average Daily Ration consumed per Cow (Pounds).*

CHARACTER OF RATION.	Hay.	Bran.	Cottonseed Meal.	Corn Meal.	Molassine Meal.
Corn meal,	18.5	2.3	1.4	4.3	–
Molassine meal,	18.6	2.3	1.4	–	4.3[1]

[1] Including 20 pounds of corn meal fed Cecile.

The average daily amount of rations fed was practically the same for both periods. This does not, however, take into account the actual dry matter fed. The small amount of corn meal that it was found necessary to feed Cecile in order to induce her to eat the Molassine is figured as Molassine meal.

TABLE VI. — *Digestible Organic Nutrients in Average Daily Rations (Pounds).*

CHARACTER OF RATION.	Crude Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Total.[1]	Nutritive Ratio.
Corn meal,	1.98	3.33	8.77	.54	15.27	1:6.7
Molassine meal,[2]	1.89	3.35	7.80	.39	13.90	1:6.4

[1] Including fat x 2.2.

[2] With corn meal fed Cecile figured as Molassine meal.

The total average daily nutrients were somewhat less for the Molassine ration than for the corn meal ration, due largely to the fact that the Molassine meal contained rather more water and less digestible matter than the corn meal.

TABLE VII. — *Herd Gain or Loss in Live Weight (Pounds).*

CHARACTER OF RATION.	Gain.
Corn meal,	15
Molassine meal,	5

The gain in weight for both periods is insignificant, and simply demonstrates that the animals were receiving sufficient food to maintain body and milk requirements.

TABLE VIII. — *Total Yield of Milk Products (Pounds).*

Corn Meal Ration.

Cows.	Total Milk (Pounds).	Daily Milk (Average).	Total Solids (Pounds).	Total Fat (Pounds).	Butter Equivalent (Fat + ⅙).	Average Per Cent. Total Solids.	Average Per Cent. Fat.
Fancy II.,	405.4	19.3	55.42	19.42	22.66	13.67	4.79
Cecile,	384.0	18.3	53.07	18.20	21.23	14.82	4.74
White,	771.8	36.8	96.24	34.04	39.71	12.47	4.41
Amy,	456.7	21.7	62.57	21.88	25.53	13.70	4.79
Betty,	377.7	18.0	53.10	18.17	21.20	14.06	4.81
Samantha II.,	715.9	34.1	89.99	26.92	31.41	12.57	3.67
Total,	3,111.5	24.7[1]	410.39	138.63	161.74	13.19[1]	4.46[1]

[1] Average.

TABLE VIII. — *Total Yield of Milk Products (Pounds)* — Continued.

Molassine Meal Ration.

Cows.	Total Milk (Pounds).	Daily Milk (Average).	Total Solids (Pounds).	Total Fat (Pounds).	Butter Equivalent (Fat + ⅙).	Average Per Cent. Total Solids.	Average Per Cent. Fat.
Fancy II.,	370.6	17.6	49.29	16.71	19.49	13.30	4.51
Cecile,	300.7	14.3	41.26	14.04	16.38	13.72	4.67
White,	631.3	30.1	75.57	25.38	29.31	11.97	4.02
Amy,	429.1	20.4	58.31	21.15	24.68	13.59	4.93
Betty,	368.3	17.5	51.19	17.75	20.71	13.90	4.82
Samantha II.,	621.3	29.6	77.35	24.54	28.63	12.45	3.95
Total,	2,721.3	21.6[1]	352.97	119.57	139.50	12.97[1]	4.38[1]

[1] Average.

It will be seen from the foregoing table that the cows produced substantially 14 per cent. more milk and 16 per cent. more solids and fat on the corn meal ration than they did on the Molassine ration. The milk produced during the corn meal period contained a slightly higher percentage of total solids and fat than did that produced in the Molassine period. This, however, may have been within the limit of error.

TABLE IX. — *Food Cost of 1 Quart of Milk and 1 Pound of Butter for Each Ration.*

CHARACTER OF RATION.	Total Cost of Ration.	Cost of 1 Quart of Milk.	Cost of 1 Pound of Butter.
Corn meal,	$42.61	$0.031	$0.26
Molassine meal,	46.19	.038	33

Adverse Influences. — 1. The fact that the cow Cecile could not be induced to eat the Molassine, and that it was necessary to substitute 1 pound of corn meal for 1 pound of Molassine. As figured, however, this should benefit the Molassine ration.

2. The hay fed did not run as uniform in quality as could have been desired. As all the cows received the same hay each day this should not affect the results obtained.

3. The total corn meal ration contained 18 pounds more dry matter than did the Molassine ration. When this is applied to the average daily ration the difference is very slight.

General Conclusions. — 1. Molassine meal is essentially a carbohydrate feed, but differs from corn meal in containing more water, fiber and ash, and less fat and carbohydrates. While the protein content is about the same, the protein of the Molassine contains approximately 70 per cent. of amido compounds which are not as valuable as true protein.

2. Molassine meal was found to contain about 470 pounds less digestible matter to the ton than corn meal.

3. In a feeding experiment with 6 cows the Molassine meal ration produced about 14 per cent. less milk and 16 per cent. less solids and fat than did the corn meal ration.

While molasses mixed with moss or peat (of which Molassine meal is a type) renders the former easily handled, and while such a mixture may be used to advantage in some cases, it is believed that at prevailing prices it is likely to prove a decidedly expensive feedstuff, especially for dairy animals.

(4) *Molassine Meal for Horses.*

Mention has already been made of the fact that mixtures of moss or peat and molasses are in common use in Germany, France and England. There is no feedstuff the value of which has been so thoroughly discussed and disputed as has this feed mixture.

The late O. Kellner [1] considered it expensive, recognizing that its nutritive value was to be found only in the 75 per cent. of molasses which it contained. He advised the use of plain molasses, or molasses mixed with bran or other feedstuff.

Lavalard,[2] one of the French authorities on the nutrition of the horse, conducted long-continued experiments, using one-fourth *Tourbe-Melassée* and three-fourths oats, corn and beans, together with some 7 to 8 pounds daily of chopped straw. He states that this combination has given the best results, the animals completely consuming the ration, which was never the case with the ordinary ration fed. He further states that as a result of feeding this ration, large numbers of cavalry horses were well nourished and equal to the work required of them, and with a noticeable decrease in the intestinal troubles which usually occur. The introduction of molasses in the ration led him to fear the injurious effects of the potash salts. His long experience, however, enables him to say that these salts acted both as a tonic and stimulant.

The writer has fed Molassine meal to farm horses and found it to be readily eaten and in no way injurious. The horses to which it was fed were in normal condition beforehand.

In spite of its worthlessness as a food, the moss serves as a satisfactory carrier of the molasses. Emphasis has already been placed upon the high cost of the Molassine meal in proportion to its nutritive value.

(5) *General Statement concerning Molasses as a Foodstuff.*

Molasses has been in use for a considerable time both in Europe and America, either fed by itself or as a component of mixed feeds for all kinds of live stock.

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[1] Die Ernährung d. Landw. Nützthiere, Sechste Auflage, p. 378.

[2] L'alimentation du Cheval, p. 62.

As a result of numerous experiments it has been shown to have substantially three-fourths the nutritive value of corn meal. Contrary to popular opinion, molasses does not improve the digestibility of other foods with which it is fed; it decreases or depresses their digestibility.[1] As a result of his reading and own experiments, the writer desires to repeat previous statements concerning the use of molasses: —

1. *For Dairy Stock.* — No advantage is to be gained by northern farmers from the use of molasses as a food in place of corn meal and similar carbohydrates. As an appetizer for cows out of condition, and for facilitating the disposal of unpalatable and inferior roughage, 2 to 3 pounds of molasses daily undoubtedly would prove helpful and economical.

2. *For fattening Beef Cattle.* — Some 3 pounds daily may be fed advantageously, especially during the finishing process, when the appetite is likely to prove fickle. The object at such times is to make the food especially palatable, and thus induce a maximum consumption, and also to secure a bright, sleek appearance.

3. *For Horses.* — In spite of the many favorable reports relative to the use of molasses, the writer is not inclined to recommend to northern feeders its indiscriminate use in the place of the cereals and their by-products. As an appetizer and tonic for horses out of condition, and for hard-worked horses, as a valuable colic preventive, and for improving the palatability of rations, 2 to 3 pounds daily of molasses undoubtedly would prove productive of satisfactory results. Frequently, however, horses that have become accustomed to molasses as a component of the ration refuse to eat freely should the molasses be removed.

(6) *How to feed Plain Molasses.*

When molasses is fed in its natural state it should be warmed if necessary, diluted somewhat with warm water, and mixed with the bulk of the grain ration or with finely cut hay or straw. Molasses may also be placed in a sack suspended in a barrel of water over night and the resulting liquid given as a drink.

2. COTTONSEED MEAL AND COTTONSEED HULLS.[2]

Cottonseed meal is the ground cake resulting from the extraction of cottonseed oil from the cottonseed kernel. Cottonseed meal containing not more than 8 per cent. fiber nor less than 40 per cent. protein is to be preferred to that containing more fiber and less protein. Our compilations of analyses of cottonseed meal made since the adoption of the feedstuff law show the following average protein, fat and fiber content for the various years: —

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[1] **Mass. Expt. Sta., 22d report, pp. 82–131.**

[2] **Prepared entirely by Mr. Smith.**

YEAR.	Number of Samples.	Protein (Per Cent.).	Fat (Per Cent.).	Fiber (Per Cent.).
1897–1902,	93	46.2	11.2	5.8
1902–1906,	190	45.4	9.6	6.4
1906–1911,	85	42.0	9.2	7.3
1911,	30	41.0	8.2	7.7
1912,	64	41.0	7.7	8.4
1913,	87	40.2	7.7	9.2
1914,	50	40.2	7.6	9.4

There is a growing tendency to incorporate more hulls in cottonseed meal, as is clearly demonstrated in the gradual and consistent increase in the fiber content of the meals collected during the last seventeen years. The preceding average does not show the worst samples, as a number of those collected during 1914 contained as high as 12 per cent. of fiber.

Cottonseed meal has long been considered the most economical and satisfactory protein concentrate that the New England dairy farmer could buy, and its value has been set forth by experiment station officials and practical feeders. If it is to continue to hold its high place this gradual decrease in its quality must stop.

Bartlett has demonstrated in a very striking manner the wide difference in the feeding value of cottonseed meal containing different proportions of fiber or hulls by actual digestion tests with sheep, as follows:[1] —

(1) *Composition of Four Grades of Cottonseed Meal used in Digestion Experiments.*

GRADE.	Water (Per Cent.).	Ash (Per Cent.).	Protein (Per Cent.).	Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Fat (Per Cent.).
Very high,	8.01	7.59	46.75	6.23	21.64	9.78
Dark colored,[2]	12.72	7.05	42.50	7.67	14.64	8.62
Medium,	11.60	6.50	34.13	13.58	19.83	8.90
Low,	9.52	4.70	23.81	21.43	30.53	6.20

[1] Bul. No. 115, Maine Experiment Station.

[2] Due to fermentation.

(2) *Digestion Coefficients with Sheep.*

Grade.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Protein (Per Cent.).	Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Fat (Per Cent.).
Very high,	90.0	95.3	83.3	–	95.9	100.0
Dark colored,[1]	85.8	89.9	82.2	–	94.7	97.2
Medium,	73.0	78.0	83.6	43.5	82.1	94.6
Low,	61.4	64.1	72.6	37.8	67.8	90.1

[1] Due to fermentation.

Pounds of Digestible Nutrients in 100 Pounds of the Different Grades of Cottonseed Meal.

Grade.	Organic Matter (Pounds).	Protein (Pounds).	Nitrogen-free Extract (Pounds).	Fat (Pounds).
Very high,	80.4	39.0	20.8	9.8
Dark colored,[1]	72.2	35.0	13.9	8.4
Medium,	63.9	28.5	16.3	7.3
Low,	55.0	17.3	16.5	5.6

[1] Due to fermentation.

It will be seen that 100 pounds of low-grade cottonseed meal contained about 30 per cent. less digestible organic matter than the high-grade material. The addition of hulls to cottonseed meal, even in small amounts, lessens its feeding value in two ways: first, it decreases its protein content; second, it impairs its digestibility. Since the quality of the meal sold in Massachusetts is gradually growing poorer, consumers have a right to know just where this decreasing feeding value is going to stop. Manufacturers claim that it is due largely to improved processes in the extraction of the cottonseed oil.

(3) *Cottonseed Feed Meal.*

Cottonseed feed meal is either a mixture of cottonseed meal and crude hulls or of cottonseed meal and cottonseed hull bran. When the mixture consists of cottonseed meal and hulls it is usually derived from the Sea Island cottonseed, to which no lint adheres, and is theoretically the entire seed (both kernel and hulls) ground together after the extraction of the oil.

Cottonseed hull bran is the cotton hull from which the lint has been removed by a special process. In the preparation of cottonseed for the manufacture of oil the lint is not entirely removed. A number of mills have been established that take the hulls from the cottonseed crushers and remove the last trace of lint. Only a small proportion of the hulls produced, however, are entirely delinted.

Here follow the analyses of cottonseed hulls, cottonseed hull bran, and cottonseed feed meal made at the experiment station: —

MATERIAL.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Cottonseed hulls,[1]	11.0	5.3	2.4	39.0	39.7	2.6
Cottonseed hull bran,	11.0	2.3	1.1	48.7	35.0	1.9
Cottonseed feed meal,[2]	10.3	21.3	4.9	39.8	19.0	4 7

[1] This analysis was made in connection with some experimental work at the experiment station prior to 1900. Owing to improved processes in the separation of meats and hulls, cottonseed hulls now contain less protein and fat than formerly.

[2] Analysis of sample used in digestion experiment.

Experiments have shown about 41 per cent. of the cottonseed hulls to be digested and utilized by ruminants, as compared with 55 per cent. in case of timothy hay. In other words, in 1 ton of material there would be 820 pounds of cottonseed hulls digested as compared with 1,100 pounds of timothy hay. Data are not available for the cottonseed hull bran, but it is not believed its digestibility is much greater. The results of a digestion trial with cottonseed feed meal made at this station follow: —

Digestion Coefficients for Cottonseed Feed Meal.

SHEEP.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V.,	59.30	47.20	73.57	32.31	61.35	102.97[1]
VI.,	57.15	51.53	76.34	19.88	61.04	98.25
Average,	58.23	49.37	74.96	26.10	61.20	100.66
High-grade cottonseed meal for comparison.	79 00	84.00	84.00	35.00	78.00	94.00

[1] This figure simply shows that all of the fat was digested, together with 2 per cent. more of the fat in the hay fed than was digested when the hay was fed alone.

The low fiber digestibility is due to the tough, woody character of the hull. This material contains only about three-fourths of the total digestible dry matter of cottonseed meal of good quality. Furthermore, since it contains much less digestible protein and two and one-half times as much total fiber as genuine cottonseed meal, it is not worth more than one-half as much for animal feeding. At the present time (October, 1914) it is being offered at a price about three-fourths that of choice cottonseed meal. Judging from its analysis it probably contains 1,000 pounds of choice cottonseed meal and 1,000 pounds of cottonseed hull bran to the ton.

(4) *Conclusions.*

I. On the basis of analyses made during the last seventeen years, it is evident that the quality of cottonseed meal sold in Massachusetts is gradually growing poorer.

II. The addition of cottonseed hulls or cottonseed hull bran to choice cottonseed meal noticeably decreases its digestibility.

III. Cottonseed feed meal, being a mixture of approximately 1,000 pounds of choice cottonseed meal and 1,000 pounds of cottonseed hull bran, does not have much over one-half the feeding value of choice cottonseed meal, while it sells for three-fourths as much.

IV. While cottonseed hulls and cottonseed hull bran can probably be used to advantage in the south, they are not worth the consideration of the northern feeder, either as a product by themselves or as an admixture in good cottonseed meal.

3. COCOA SHELLS.

Cocoa shells are the hard, outside coating or bran of the cocoa bean. They are dark brown in appearance and brittle in texture. They comprise from 10 to 16 per cent. of the bean. The entire residue, however, removed from the bean and included as cocoa shells amounts to from 16 to 25 per cent. The output for the United States has been estimated at 6,700 tons. Up to the present time their use in this country as a feeding stuff has been quite limited, although they are now known to be used in several poultry mashes and in one brand of calf meal. In Europe they are used as a partial food for horses and cattle and as an adulterant for oil cakes. Large quantities are also used by the Swiss as a feed for draft oxen, thus utilizing the residue from their chocolate factories. It is held that they act as a stimulant to the nerves and muscles and enable the animals to do a greater amount of work.[1]

(1) *Chemical Composition.*

NUMBER.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
A,[2]	4.50	8.43	13.90	12.65	55.61	4.91
B,[3]	10.00	7.40	14.30	15.80	46.30	6.20

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[1] Pott, Handbuch d. thierschen Ernährung, etc., 3rd Bande pp. 136–141.

[2] As used in digestion trial.

[3] Kellner's tabulation.

The difference between the American and German figures is within the limits of variations in different samples.[1]

(2) *Digestion Coefficients with Sheep.*

SHEEP.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
I.,	56.55	13.04	4.41	41.41	75.75	100.44
II.,	58.59	14.32	18 52	59.91	71.16	100.54
Average,	57.52	13.64	11.47	50.66	73.46	100.48
German coefficients,[2]	36.00	–	5.00	21.00	48.00	84.00

It will be seen that the product used by Kellner for some reason was much less digestible than that used by ourselves.

Pounds Digestible in 100 Pounds of Shells.

	Massachusetts.	Kellner.
Protein,	1.53	.71
Fiber,	6.45	3.31
Nitrogen-free extract,	40.60	22.22
Fat,	4 91	5.21
Total,	53 49	31.45

It is quite evident that the proteid matter is only slightly digestible and may be considered a negligible quantity; hence the value of the product consists of the digestible fiber, fat and extract matter. On the basis of his results, Kellner remarks that the cocoa shells have no more feeding value than straw.

The net available energy on the basis of our own digestion trials is 63 as compared with corn meal equal to 100. When, however, one considers their non-palatability and their rather objectionable appearance, together with the results of other investigations, it does not seem advisable to rate them as having more than one-half the feeding value of corn meal.

(3) *Feeding Trials.*

A number of milch cows were fed from 2 to 3 pounds, daily, of the cocoa shells, both ground and unground, mixed with other grains. One cow was induced to eat as high as 5 pounds when mixed with malt sprouts and corn meal. It was difficult to induce the animals to eat the shells unground. It was not possible to make any comparative tests of the effect of a definite amount of ground shells upon milk production, as compared with some other grain, for the reason that a sufficient number of animals was not available at the time. The observation simply indicated that the animals would eat the ground shells when mixed with other grain.

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[1] Foreign workers have shown the presence of the alkaloids caffein and theobromine, also a considerable percentage of pentosans. Fowler, in the laboratory of the Massachusetts Agricultural College, has determined the percentages of the alkaloids, and has found also 8.3 per cent. of pentosans, 7.3 per cent. of galactans, a little over 1 per cent. of starch and traces of sugar.

[2] Obtained by Kellner.

(4) *Manurial Value.*

The average of two analyses of cocoa shells showed them to contain: —

	Per Cent.
Nitrogen,	2.45
Potash,	2.92
Phosphoric acid,	.69

The nitrogen was found to be about one-third available. The balance would, of course, be of use to plants from year to year. Based on the above analyses the shells have a commercial value of about $6 a ton as a fertilizer.

(5) *Conclusions.*

The results of our study of cocoa shells show them to have a feeding value about one-half as high as corn meal. They are best suited for dairy animals, while in foreign countries they are used also as a partial food for horses. Dairy animals will, as a rule, not eat them unground. If they can be had at a sufficiently low price the ground shells can be used in amounts of from 1 to 3 pounds daily mixed with the grain ration. Because of their low digestibility it is doubtful if they can be purchased to advantage as a food for horses. As a source of fertility they are evidently not worth much more than the cost of cartage and spreading. They may also be used for bedding purposes.

4. WHEAT OR GRAIN SCREENINGS.

Grain screenings consist of the light seed, weed seeds, chaff and dirt separated from grain in the process of winnowing. The composition of grain screenings depends upon the kind of seed from which they are separated and upon their freedom from dirt and chaff. They necessarily vary so much in composition that no general statement as to their value can be made. Where screenings contain a large amount of straw and chaff they cannot be considered much superior to straw; on the other hand, screenings free from chaff and dirt, and containing nothing but light grain and weed seed, possess considerable feeding value.

Grain screenings are but little used by themselves as a feeding stuff in Massachusetts, but are found on the market as a component of molasses feeds, of wheat by-products, and occasionally of the so-called stock feeds. In the west screenings have been used for fattening sheep. Formerly one objection to the use of screenings in proprietary stock feeds was due to the fact that they contained many whole weed seeds which passed through the animal undigested and found their way on to the land ready to grow, and thus added to the labor of keeping cultivated land free from weeds. With improved processes of manufacture the screenings are now mostly finely ground and their germinating property destroyed.

(1) *Physical Appearance.*

Two lots of screenings were obtained from a commission merchant in Milwaukee. They were quite similar in physical appearance. The following materials were identified in sample No. 1; light oats, oat hulls, wheat, wheat refuse, smutted grain, yellow foxtail, green foxtail, corn cockle, bindweed, flax, lady's thumb, charlock, wild mustard, rape, lamb's-quarters, large smartweed, chaff of various sorts, wild sunflower, pigweed, timothy, shepherd's-purse, chess, oat grass, wild oats, rye and corn, together with a few unidentified seeds. Both lots used must be considered as of good quality for screenings, as they did not contain excessive amounts of broken straw, chaff or dirt.

(2) *Chemical Composition.*

SAMPLE.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
No. 1,	8.0	4.9	15.6	9.1	54.7	7.7
No. 2,	11.5	3.8	15.5	7.3	57.2	4.7
Wheat bran for comparison,	10.0	6.2	16.1	10.0	53.3	4.4

(3) *Digestion Coefficients obtained with Sheep.*

Lot I.

SHEEP.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V.,	57.57	27.36	78.88	–	63.76	86.18
VI.,	60.65	26.10	82.97	–	65.33	87.41
Average,	59.11	26.73	80.93	–	64.55	86.80
Lot II.						
V.,	64.93	–	62.26	–	79.54	87.67
VI.,	68.58	–	63.01	–	84.12	92.50
Average,	66.76	–	62.64	–	81.83	90.09
Average for both lots,	62.94	–	71.79	–	73.19	88.45
Wheat bran for comparison,	66.00	–	77.00	39.00	71.00	63.00

The difference shown in the digestibility of the two lots can probably be accounted for by the fact that the first lot contained more fiber and less nitrogen-free extract than did the second. The fiber contained in both lots did not appear to be at all digestible, indicating somewhat of a depressing effect of the wheat screenings upon the fiber digestibility of the hay, and also that the fiber contained in the weed seeds of the screenings was of decidedly inferior character. In chemical composition and digestibility the screenings did not appear to vary greatly from wheat bran.

(4) *Conclusions.*

The chemical composition and the results of the digestion trials indicate that these particular screenings possessed a considerable nutritive value. Owing to the wide difference in the character of screenings the results obtained should not be considered as representative for all classes of screenings, but only for those reasonably free from dirt, chaff, straw and an excess of noxious seeds. When used either by themselves, or as a component of molasses, wheat or stock feeds, they should be finely ground, and would then approximate wheat bran in the amount of nutritive material they contain.

5. FLAX SHIVES.

Flax shives, sometimes incorrectly called flax bran, consist of the ground refuse stalks and pods of the flax plant. They are sometimes used as a component of stock and molasses feed, and have been found on sale in Massachusetts as a substitute for wheat bran. They have the appearance of finely ground hay. The analysis of two samples at the experiment station showed that this material may vary widely in chemical composition.

(1) *Chemical Composition.*

Sample.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
No. 1,	6.8	12.1	6.1	45.2	27.7	2.1
No. 2,[1]	10.0	5.0	14.9	32.3	34.9	2.9
Average,	8.4	8.6	10.5	38.8	31.3	2.5

[1] Used in digestion trials.

(2) *Digestion Coefficients obtained with Sheep.*

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V.,	42.94	21.86	79.98	22.00	41.27	92.26
VI.,	47.82	23.69	82.08	29.58	45.63	93.09
Average,	45.38	22.78	81.03	25.79	43.45	92.68

This experiment showed flax shives to have a digestibility of about 45 per cent. as compared with 66 per cent. for wheat bran; in other words, 1 ton of flax shives would contain only 900 pounds of digestible matter, while wheat bran contains about 1,140 pounds. Their high fiber content requires considerable extra energy for their digestion. This fact, coupled with their small amount of protein and their low total digestibility, renders them in no way economical for eastern feeders. As a component of mixed feed they must be considered as a filler or adulterant. They may serve, where they are produced, as a partial feed for sheep or steers.

6. MELLEN'S FOOD REFUSE.

This material is sold to a limited extent in eastern Massachusetts and consists of the residue resulting from the manufacture of an infant food. The original ingredients used in this food are malt, flour and bran, the soluble and more digestible parts of these materials going into the infant food.

(1) *Chemical Composition.*

	Per Cent.
Water,	6.98
Ash,	4.07
Protein,	12.57
Fiber,	16.97
Nitrogen-free extract,	55.48
Fat,	3.93

(2) *Digestion Coefficients with Sheep.*

SHEEP.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V.,	54.13	–	50.64	42.83	61.85	83.33
VI.,	48.17	–	39.24	46.23	54.87	83.43
Average,	51.15	–	44.94	44.53	58.36	83.38

Pounds Digestible Organic Matter in 100.

Protein,	5.66
Fiber,	7.64
Nitrogen-free extract,	32.18
Fat,	3.26
Total,	48.74

Mellen's Food refuse was found to contain 975 pounds of digestible organic nutrients as compared with 1,140 pounds for wheat bran. Its low digestibility is due, no doubt, to the fact that the more digestible parts of the ingredients used are to be found in the prepared food itself. It has a net energy value of 44.58 therms as compared with 49 therms for wheat bran, or as 90 is to 100. It could be used as a component of the grain ration for either cattle or horses, providing it could be purchased for substantially three-fourths of the cost of wheat bran. Two to three pounds daily would be considered a normal amount mixed with other higher grade concentrates.

7. CXX FEED.

A by-product known as CXX Feed has been found to some extent on the Massachusetts market. This material bears the name of the Postum Cereal Company, and is supposedly the insoluble residue of Instant Postum, prepared by roasting a mixture of wheat, wheat bran and molasses.

(1) *Chemical Composition.*

	Per Cent.
Water,	9.18
Ash,	2.49
Protein,	17.77
Fiber,	16.45
Nitrogen-free extract,	51.28
Fat,	2.83

(2) *Digestion Coefficients with Sheep.*

SHEEP.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract	Fat.
V.,	45.73	-	19.85	20.00	64.97	77.26
VI.,	40.08	-	19.76	6.76	59.98	78.53
Average,	42.91	-	19.81	13.39	62.48	77.90

Pounds Digestible Organic Matter in 100.

Protein,	3.52
Fiber,	2.21
Nitrogen-free extract,	32.04
Fat,	2.20
Total,	39.97

The results of the experiment show the CXX Feed to have a very low digestibility, probably due to the roasting that the product undergoes, and to the fact that much of the very digestible soluble carbohydrates has been removed. The protein and fiber appear to be of little nutritive value, and the material as a whole must be pronounced quite inferior for feeding purposes.

BULLETIN No. 159 DECEMBER, 1914

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

THE TECHNICAL DESCRIPTION OF APPLES

By J. K. SHAW

This bulletin discusses methods and terms used in the systematic and commercial description of apples, both trees and fruit. It is intended for the use of students and investigators in pomology.

Requests for bulletins should be addressed to the
Agricultural Experiment Station,
Amherst, Mass.

Massachusetts Agricultural Experiment Station.

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[1] On leave.

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Approved by
The State Board of Publication.

THE TECHNICAL DESCRIPTION OF APPLES.

BY J. K. SHAW.

Introduction.

This paper aims to set forth certain methods and terms which the writer has found useful in the description of apple trees and fruits. It contains little that is new to the pomological world, but is, rather, a compilation of methods and terms of description gathered from many pomologists of our own and former times. This matter has been brought together and arranged in a definite and systematic manner. It is not intended to be complete in itself, but should be used in connection with a good textbook or reference work on systematic pomology.

The best presentation of tree description may be found in Thomas' "American Fruit Culturist." For description of the fruit, Beach's "Apples of New York" and Hansen, in the "American Horticultural Manual" Vol. II., are the most complete and satisfactory. Other books giving helpful discussions, especially of fruit characters, are Waugh's "Systematic Pomology," Warder's "American Pomology" and Robert Hogg's "British Pomology." Among the German works, Lucas' "Einleitung in das Studium der Pomologie" is most complete and useful.

A written description of a variety of apples may be made from one or more typical specimens before the writer, or it may be written from memory or compiled from notes after one has become familiar with the variety. Two kinds of variety description ought to be recognized, — first, a systematic description which takes account of all characters of the tree and fruit which can have taxonomic value, and second, the commercial description, which is a presentation of all the characters and qualities of a variety that are of interest and value to the man interested in the practice of fruit growing. Most variety descriptions belong to the former class, though some give considerable attention to the commercial phase. Commercial descriptions are of much the greater interest and value to the practical orchardist, and they ought to be more clearly recognized and we ought to have more of them. The distinction between the two is an arbitrary one, and is made for convenience and for the sake of emphasizing those qualities that are of paramount interest to the commercial fruit grower.

The Systematic Description.

The systematic description involves all the characters of the tree and fruit having taxonomic value. In the description blank suggested here an effort has been made to classify these characters, and as far as possible to reduce each to a single unit. Under each heading a single character is to be considered and described, usually with one appropriate word. Rarely will several words be required. In the text and in Fig. 1 descriptive words are suggested. While these are not all that may be required, we believe that additional ones will not often be needed, with the exception of qualifying adverbs. Words such as *very*, *slightly*, *much*, *rarely* and many others will be called into use freely, but it is felt that it is unnecessary to suggest them all through the discussion of the description blank. Where additional terms are used one should be careful that he understands the relation of the new term to those given, and if necessary he should somewhere explain its meaning and relationship. One of the confusing things in fruit descriptions is the use in individual descriptions of different terms with nearly or quite the same meaning, or of a single term with slightly different meanings. Of course, it is impossible to altogether avoid such confusion because apples vary so greatly, but every effort should be made to make things as definite and exact as possible.

In making a systematic description one should state, either directly or by implication, the scope of his description,— whether it is of a single apple, a plate of five specimens, or the variety as it grows over a certain section of the country, as Massachusetts, New England, the Central Mississippi valley or North America. The description of a few specimens is a comparatively simple matter, and may be made in a few minutes by the trained pomologist with the specimens before him. The description of a variety as it grows over a considerable area is more complicated, and can be made only after a thorough study of the behavior all over the district comprehended in the description. In such descriptions we should strive to describe the type of the variety, but as a variety may vary greatly if a district of any size is considered, it becomes very desirable to delimit as well as we can the range of variation. Perhaps the best method to pursue is to give the type and follow it immediately by a statement of the variation. Thus we may describe the form of the Ben Davis for North America as "*roundish-conic*, varying from *oblate-conic* to *oblong-conic*," and other characters in a similar fashion.

Of course such a description will be cumbersome, and for many purposes an abridged form may be found sufficiently complete and more acceptable. Nevertheless, for a thorough college course in systematic pomology, or for exact descriptive work in experimentation, this type of description ought to have a place.

In the description of the individual tree or fruit the location or source should always be given, and if possible the soil and cultural conditions under which it was grown. It is well to give the date on which the description was made, and of course the name of the person responsible for the work.

Tree Description.

Tree. — In the systematic description of the tree the first thing stated is its age. If not definitely known it should be estimated. The next point is the size which may be *small*, *medium* or *large*. This should of course be

Variety From Soil

TREE, age size { *small* *medium* *large* vigor *weak, strong, moderate, very strong*

form { *flat* *oval* *spreading* *round* *upright* *drooping* density *dense, medium, open*

SHOOTS, length { *short, long* *medium* size { *stout, medium* *slender* direction { *upright, drooping* *diverging, ascending* *spreading, regular*

straightness { *straight* *zigzag* curvature { *curved* *not curved* internodes *short, medium, long*

BARK, color *green, yellow, orange, red* scarf-skin

surface *shining, medium, dull* thickness { *thick* *medium* *thin* pubescence { *much* *medium* *thin* *fine* *coarse*

Lenticels, number *few, medium, many* size *small, medium, large*

form { *oval* *roundish* *flattened* color { *white* *gray* *brown* position *even, raised*

WOOD, color *green, yellow* hardness *hard, medium, soft*

flexibility *stiff, medium, flexible* pith *narrow, medium, wide*

BUDS, size { *small* *medium* *large* form { *roundish, ovate* *oval, slender* color *brown, red*

position *free, appressed* surface *pubescent, smooth*

LEAVES, Petiole, length *long, medium, short* size *slender, medium, stout*

color *green, red* surface *smooth, pubescent*

Stipules, size *small, medium, large* form *wide, medium, narrow*

Blade, size { *very small, medium* *small, above medium* *below medium, large* *very large* form *flat, folded* mid-rib *straight, reflexed*

sides { *even, waved* *wrinkled, crumpled* outline *oval, ovate, oblong*

base { *broad, rounded* *narrow* apex { *broad, medium* *narrow* point { *small* *medium* *large* *blunt* *acute* *acuminate*

general color { *light green* *dark green* vein color *green, red*

position { *erect, spreading* *drooping* thickness *thick, medium, thin*

serratures, nature { *sharply serrate* *serrate, dentate* *crenate* direction { *strongly forward* *forward, outward*

size *small, medium, large* regularity *regular, irregular, double*

curvature *curved, straight* depth { *deep* *medium* *shallow* space *distinct, indistinct.*

surface *dull, shining* texture *coarse, fine* pubescence { *short* *long* *fine* *coarse* *woolly*

FLOWER

CHARACTERISTICS

Described by Date

Massachusetts Experiment Station Department of Pomology

FIG. 1.—Description blank, for the tree, with terms used.

stated in relation to the age of the tree. The size of the tree is determined by the rate of growth in the past, while the vigor measures its current rate of growth as indicated by the length and size of the shoots and the color, size and abundance of the foliage. In vigor the tree may be *weak, moderate, strong* or *very strong.* Next comes the form of the tree which is often characteristic and important in trees that are approaching or have reached maturity. Most varieties begin to take on their characteristic form by the time they are four to six years old. The form of the head may be *flat, round, oval, upright, spreading* or *drooping.* The density of the head is determined by the thickness of its branches and by the abundance of their foliage. It may be *dense, medium* or *open.*

Shoots. — The shoots comprise the last or current season's growth of the more vigorous branches. In very young trees they indicate in some measure the adult form of the tree. Their length should be estimated on the basis of a full season's growth. They may be *short, medium* or *long,* and if the average length in centimeters or inches can be given, so much the better. In size they may be *stout, medium* or *slender,* and if the diameter preferably in millimeters, 2 inches or less above the last annual ring, is given, it adds to definiteness. The direction of the shoots is of special significance in very young trees. They may be *upright, diverging, spreading, drooping, ascending* or *irregular.* The direction may be quite satisfactorily determined by means of a simple protractor. It should be taken on a main branch that is perpendicular. Shoots that are diverging form an angle of about 45°, while ascending shoots are like upright ones, except that they are more distinctly curved near the base. Under straightness we record whether the shoots are *straight* or *zigzag.* In the latter case the successive internodes do not lie in the same direction, but alternate back and forth. Under curvature the shoots may be more or less *curved* or *not curved.* The length of the internodes varies somewhat in different varieties, and they may be *short, medium* or *long.*

Bark. — The color of the bark varies with the season. In the summer it is some shade of *greenish olive* or *yellowish olive,* and the color darkens with the falling of the leaves to a *greenish, yellowish* or *reddish brown.* The full description of a variety ought to include both the summer color and the winter color. The summer color should be taken on wood of the previous season's growth, as that of the current season's growth is apt to be variable. The surface may be *shining* or *dull,* and in thickness the bark may be *thick, medium* or *thin.* The amount of pubescence on the young shoots — *much, medium* or *little* — should be mentioned, and whether it is *fine* or *coarse.*

The lenticels are often characteristic of the variety, and they seem to be quite dependable in identification. The number — *few, medium* or *many* — is most valuable, and should be carefully noted. Their size — *small, medium* or *large* — should find mention, also their form, which is commonly *roundish* but may be *oval* or *flattened.* Their color is commonly *whitish, gray* or *brown.* The position of the lenticels is of especial importance, and refers to whether they are *raised* above the surface or *even* with it. This is best determined by rubbing gently the surface of the two-year-old wood, or well-matured wood of the current season's growth, with the finger or thumb.

Wood. — The color of the fresh-cut wood will generally be *greenish* or *yellowish.* Experience in pruning or whip grafting will soon demonstrate that varieties vary much in the hardness of their wood. It may be determined — as *hard, medium* or *soft* — by cutting a branch about one-half inch in diameter. The flexibility is judged by bending a small branch thus showing whether it is *stiff, medium* or *flexible.* This character is of practical importance as indicating the danger of the tree breaking under a load of fruit. The diameter of the pith may vary somewhat, and may be said to be *narrow, medium* or *wide.*

Buds. — The buds are best described from near the middle of the current season's growth and during the dormant season of the trees. We note the size, whether *small, medium* or *large;* their form, whether *roundish, oval, ovate* or *slender;* and their color, usually some shade of *brown* or *red.* Their position with respect to the shoot may vary, so that the buds are *appressed* or clinging closely to the shoot, or they may be *free.* The surface may be *pubescent* or *smooth.*

Leaves. — The leaves of different varieties of apples are very characteristic, and offer opportunities for identification almost equal to the fruit, especially if observations can be made during the middle or the latter part of the summer, after the leaves have assumed their characteristic forms. It is necessary to use great care in the choice of specimens for description. Those near or just below the middle of the current season's growth should be chosen. Leaves growing on spurs from older wood should be ignored, as they are apt to be variable and quite unlike those on the free-growing shoots. Upright shoots well exposed to light and air, such as those in the topmost part of the tree, are to be preferred. The leaf is divided into stipules, petiole and blade. The petiole may be *long, medium* or *short,* and in size it may be *slender, medium* or *stout.* The color may be *green,* but usually it is more or less tinged with some shade of *red.* In colored petioles the amount and intensity of coloration increases with the maturity of the leaf. The surface of the petiole may be *smooth* or more or less *pubescent.*

The stipules may be *small, medium* or *large* or especially late in the season there may be *none;* in form they may be *wide, medium* or *narrow.*

In the description of the blade we consider first the size, which may be *small, below medium, medium, above medium* or *large.* In order to establish a standard of judgment of the size of leaves the following measurements of the combined length and breadth are suggested. In taking measurements the leaf should be spread out flat, and the point as defined on page 78 should be ignored.

Combined Length and Breadth.

	Inches.	Millimeters.
Very small,	Up to 4	Below 100
Small,	4-4½	100-115
Below medium,	4½-5⅛	115-130
Medium,	5⅛-6	130-150
Above medium,	6-7	150-175
Large,	7-8¼	175-205
Very large,	Over 8¼	Over 205

Form refers to the relation of the right and left sides of the leaf. If they lie in approximately the same plane the leaf is said to be *flat;* if they bend upward the leaf is more or less *folded.* The midrib may be *straight,* or if curved backward or downward it is said to be *reflexed.* The sides of the leaves may be *even,* or they may be more or less *waved* when there are not over three "waves," and *wrinkled* when there are a greater number. When the surface of the blade is more or less irregular it is said to be *crumpled.* A leaf may present various combinations of these characters. It may be *folded, reflexed* and *even; flat, straight* and *waved;* or it may present other combinations of these characters. Qualifying adverbs indicating the degree to which the leaf is folded, waved or reflexed may be freely introduced. The accompanying plates show characteristic leaves from a number of common varieties. These leaf characters have not been widely recognized, but the writer has found them peculiar to the several varieties and extremely useful in identification; in fact, one may recognize many varieties quite positively by them alone. They are most striking from midsummer until near the time of leaf fall.

The outline of the leaf is usually nearly *oval;* it may be *broad oval* or *narrow oval.* Sometimes it approaches *ovate, oblong* or *roundish.* The base includes the proximal one-third of the leaf, and it may be *broad, rounded* or *narrow,* while the apex includes the distal one-third excluding the point, and may be *broad, medium* or *narrow.*

There is usually a more or less distinct point which may be *small, medium* or *large,* also *blunt, acute* or *acuminate.*

The general color of the normal leaf is always some shade of *green,* usually *light* or *dark;* but may be *grayish, bluish* or *yellowish green.* The vein color is frequently tinged with *reddish* or *pinkish red.* The position of the leaf is its relation to the shoot on which it is borne, and it may be *erect, spreading* or *drooping,* the spreading leaf forming an angle of from 45° to 90° with the branch. Next comes thickness, and the leaf blade may be *thick, medium* or *thin.* The term "serratures" includes all forms of indentation of the margin of the leaf, and their nature may be *sharply serrate,*

serrate or *crenate*, rarely approaching *dentate*. The direction of the serratures is largely indicated by their nature, but it may be useful to make a closer specification on this point, as this is an important one in description. Their direction may be more or less *forward* or, rarely, almost *outward*. The size of the serratures is important, and should be taken strictly in proportion to the size of the leaf and not as to their absolute size. They may be *small*, *medium* or *large*. Their regularity is an important point, and they may be *regular*, *irregular* or *double*.

Sometimes the serratures are distinctly *curved*, in other cases they are *straight*, their depth is closely correlated with size, but it may add to definiteness to specify that they are *deep*, *medium* or *shallow*. Space refers to the amount of separation of the individual serratures; if widely separated they are *distinct*, if set closely they are *indistinct*. In describing the surface and texture of the blade we refer to the upper surface, while the pubescence is found on the lower surface only. The surface may be *dull* or *shining*, the texture *coarse* or *fine*, and the pubescence *short* or *long*, *fine*, *coarse* or *woolly*.

Flower. — The flower presents characters of value in systematic description, but it is available only for a brief period. Apple flowers vary in size and color, in the form of their parts, and probably in other characters. The writer has had so little opportunity to study apple flowers that he hardly feels like attempting any discussion of their exact description. Space is provided in the blank suggested for mention of such points as seem worthy of specific description.

Finally, under the heading "characteristics" we may sum up in a few words the specific characters that serve to distinguish the variety described. Careful study of any variety will usually reveal certain things about the leaves, twigs or general form of the tree that serve to identify it, and a terse recapitulation of these will be found very useful.

Fruit Description.

Size. — In the description of the fruit the first point that we consider is size. This may vary from *very small* to *very large*, or even to *extremely large*. The importance of stating the size in definite units, as inches or millimeters, as discussed on page 87, cannot be too strongly emphasized if exact work is desired. In the opinion of the writer the relation between the descriptive terms suggested and actual measurements of the cross diameter ought to be about as follows: —

APPLE, name

Size { *very small / small* } *below medium / medium* *above medium / large* *very large / extremely large* uniformity { *uniform / not uniform* }

Form { *oblate / globose* } *ovate / conic* *oblong / truncate* base { *narrow / rounded* } *broad / flattened* apex { *conic / narrow / rounded* } *broad / flattened*

cross-section { *round / oval / pentagonal* } *regular / irregular* sides { *equal / unequal* } uniformity { *uniform / not uniform* }

Color { *greenish / yellowish* } over-color { *red, crimson / scarlet, pink* } amount, %

disposition { *blushed, streaked / mottled, striped, splashed* } russet { *dense, irregular / thin, scattered* }

Bloom, amount { *much / medium / little* } kind { *waxy / greasy* }

Skin, thickness { *thick / medium, thin* } texture { *tough / medium, tender* } surface { *smooth / rough / lumpy* } *shining / dull*

Dots { *conspicuous, obscure / inconspicuous* } number { *many / medium / few* } size { *minute, small / medium, large* } form { *round, stellate / angular, areolar* }

color *white, gray, brown* distribution { *uniform / not uniform* } prominence { *sunken, even / raised, submerged* }

Cavity, depth { *deep, medium / shallow* } breadth { *wide, medium / narrow* } sides { *abrupt, steep / flaring* }

vertical outline { *acuminate / acute, obtuse* } cross-section { *round / oval / triangular / pentagonal* } markings { *russet / none* }

Stem, length { *long / medium / short* } size { *stout, clubbed / medium / slender* } direction { *straight / inclined / curved* } color { *brown / green* } surface { *smooth / pubescent* }

Basin, depth *as with cavity* breadth sides

vertical outline *as with cavity* cross-section { *wavy, ribbed / folded* } markings { *leather / cracked* }

Calyx, *open, closed* size *small, medium, large* surface *smooth, pubescent*

Calyx segments, size { *small / medium, large* } form { *obtuse, acute / acuminate* } position { *connivent / convergent / reflexed* }

Tube, length { *short / medium / long* } breadth { *wide / medium / narrow* } form { *funnel-form / conic* } stamens { *basal / median / marginal* } pistil point { *present / absent* }

ore { *axile / abaxile* } size { *small / medium / large* } position { *sessile / median / distant* } form { *oblate, oval / roundish / oblong, ovate* } core-lines { *distant / meeting / clasping* }

Cells *open, closed* size *small, medium, large* symmetry *symmetrical, unsymmetrical*

Carpels, form { *elliptical / oblong / ovate / oval / roundish / obovate* } apex { *acute, obtuse / mucronate / emarginate* } surface { *entire, slit / tufted* } concavity { *little / medium / great* }

Seeds, number *few, many* condition { *plump / medium / shriveled* } size { *small / medium / large* } color { *brown / olive / gray* }

cross-section { *roundish, oval / flattened* } longitudinal section { *long, obtuse, acute / short, acuminate* }

Axis, length *long, medium, short* direction *straight, inclined*

Flesh, color *white, yellow, green* texture { *fine / medium / coarse* } *buttery / melting, firm / breaking / crisp* juice { *little / medium, much* }

Flavor *acid, sub-acid, sweet* quality { *poor / medium* } *good / very good* *excellent / best*

Remarks

Specimens from Described by Date

Massachusetts Experiment Station Department of Pomology

FIG. 2.—Description blank for the fruit, with terms used.

	Inches.	Millimeters.
Very small,	Below 1⅝	Below 35
Small,	1⅝–2	35–50
Below medium,	2–2⅜	50–60
Medium,	2⅜–2¾	60–70
Above medium,	2¾–3⅛	70–80
Large,	3⅛–3⅝	80–95
Very large,	3⅝–4¼	95–110
Extremely large,	Over 4¼	Over 110

The measurements in inches are not in all cases exactly the same as the corresponding ones in millimeters, but it seems wiser to adhere to the use of less complicated fractions, even at a slight sacrifice of accuracy. The Siberian crabs should be considered in a class apart, and the above measurements will not hold for them. Probably most pomologists would give some consideration to the axial diameter in connection with size, but it is certainly of less importance than the cross diameter, and it would seem that the minimizing of such consideration would render descriptions simpler and more exact. The relation of the two diameters is brought out clearly in the description of form. Some varieties will run quite uniform in size, while others are more or less variable. This may be appropriately described under uniformity in size.

Form. — Pomologists are agreed that the form of a variety is most important, and therefore it should be described with care. In the present outline, under the term "form," is described only the general form of the fruit, leaving some of its divisions for consideration under the subheads. The form may be described as *oblate*, *globose*, *ovate*, *conic*, *oblong* or *truncate*. It is commonly said that an apple is oblate when the axial diameter is less than the cross diameter, and this is amply true; but when it is further said that in a globose apple the two diameters are equal, it is not true, if the actual measurement of the apple is considered. It may appear so to the eye, but owing to the indentation of the cavity and basin the cross diameter of such an apple is much the greater. Where the two are equal the apple would often be called oblong. For the reason given above the impression through the eye, which sees the general outline of the apple only, ignoring the flattening of the base and apex, and the actual measurement are unlike. The term "roundish" is commonly used instead of globose, but to us the latter seems the more exact and desirable term. The use of combinations of the terms given, such as *oblate-conic*, and of qualifying adverbs is often desirable and helpful.

After describing the form of the apple as a whole, special consideration is given to the base and the apex, the former comprising about one-third of the stem end, and the latter about one-third of the blossom end, of the apple. Each of these may be *conic, narrow, rounded, broad* or even *flattened.*

The cross section should be taken midway between the ends of the apple and at right angles to the axis. Two questions are to be answered under this heading — the first, whether the general outline approximates a circle, in which case it is said to be *round,* or if the apple is compressed, when the cross section will be *oval;* the second question is whether the outline is *regular, irregular* or *pentagonal.* Commonly, one cheek of an apple develops more fully than the opposite one, due apparently to better exposure to the sunlight, in which case the sides are said to be more or less *unequal.* As with size, we may find much or little uniformity in form within a variety. If a single specimen is being described no entry can, of course, be made under uniformity.

Color. — In the description of color a sharp distinction ought to be made between the greenish or yellowish ground color and the reddish over-color, for they are entirely different in their nature and significance. The former, designated simply as color, is some shade of *green, yellow* or, rarely, almost *white;* the latter is generally defined as some sort of *red,* either as *light* or *dark,* though some may prefer to consider red as a generic term and use in description such terms as *scarlet, crimson,* etc. The amount of over-color should be stated in the percentage of surface covered, and if more than one specimen is considered two numbers should be given, one representing the poorest and the other the best colored specimens. The disposition of the color is likely to be characteristic. It may be evenly spread over the fruit, in which case it is said to be *blushed,* or it may be unevenly disposed, *streaked, striped* or *splashed,* according to whether the markings are long and narrow, extending over nearly the whole cheek of the apple, of medium length or short and broad. Combinations of streaks, stripes and splashes often occur, and almost always with one or more of them there is interspersed other coloration that may be disposed irregularly and is said to be *mottled,* so that often an apple is *striped, splashed* and *mottled,* and on the sunny side the color may deepen to a *blush;* that is, the stripes and splashes are obscured by the higher development of color over the whole cheek. In naming colors or kinds of distribution it is best to always give them in order of abundance, giving the prevailing kind first. Russet may appear over the whole fruit or in the cavity only. In the latter case it finds mention under cavity markings, while in the former case it is described under russet as *dense* or *thin,* or it may be *irregular,* especially if it is not normal, but the result of unfavorable environmental conditions.

Bloom. — The amount of bloom is best ascertained by scraping the surface with a sharp knife, and recorded as *much* or *little* and the kind as *waxy* or *greasy.*

Skin. — The judgment of the observer of the thickness of the skin, whether *thick, medium* or *thin,* and the toughness, whether *tough, medium* or *tender,* are to be recorded under the proper heads. Under "surface" we note whether it is *smooth, rough* or *lumpy,* and whether it is *shining* or *dull,* also the presence of one or more *suture lines*, and the presence and nature of a *scarf skin*.

Dots. — The dots are often characteristic and valuable in description or identification. They are always found, and the first question is whether they are *conspicuous*, *distinct*, *inconspicuous* or *obscure*. This depends on several factors, such as number, size and color, so we proceed to describe these in turn. The number may be *many*, *few* or *scattering*. Their size may be *minute*, *small*, *medium* or *large*, also the size may be uniform or variable, so that they may be said to be *uniformly large* or *small* to *large*. The form of the dots may be *round*, *oval*, *angular*, *stellate* or *areolar*. Their color may be *white*, *gray* or *brown*, and the distribution *uniform*, or they may be more or less centered upon the apex of the fruit. Under "prominence" is stated whether they are *raised*, *even*, *sunken* or *submerged*.

Cavity. — Under "cavity" we describe first the depth, whether *deep*, *medium* or *shallow*, then the breadth, whether *wide*, *medium* or *narrow*, next the sides, whether *abrupt*, *steep* or *flaring*. The vertical outline, described as *acuminate*, *acute* or *obtuse*, is practically a repetition of the description of the side, and perhaps one of them might be omitted without loss. If so, we would prefer to retain the former, though the terms given under vertical outline are probably more commonly used. Under "cross section" is given the outline of a section taken about midway of the cavity. It may be *round* or *oval*, *triangular*, *pentagonal* or *irregular*. If it has a fleshy protuberance known as a lip it should be here stated. The presence of *russet* should be noted under "markings," and if the russet is *stellate* or *spreading* beyond the cavity it should be mentioned.

Stem. — Following the description of the cavity we naturally consider the stem, — the length, whether *long*, *medium* or *short*, and the size, whether *stout*, *medium* or *slender*, also if it is *clubbed*. Next we come to its direction in relation to the axis of the fruit. If it lies in the same line it is *straight*, and if not it is *inclined*, in which case it may or may not be *curved*. Next we have the color, usually some shade of *brown* or *green*, and the surface, which is *smooth* or *pubescent*.

Basin. — In the description of the basin much the same terms may be used as with the cavity, but it should be noted that the basin is formed differently from the cavity, so that the descriptive terms have a different significance, that is, the basin is always much broader at the bottom, more obtuse, and generally more shallow than the cavity. Some additional terms may be required in describing the cross section, such as *wavy*, *ribbed* or *folded*. The basin is rarely if ever russeted unless the whole fruit is russet, but occasionally we find a variety that is *leather cracked*.

Calyx. — Under "calyx" it should be stated whether it is *open* or *closed*, then follows the size, *small*, *medium* or *large*, and the surface, whether *smooth* or *pubescent*. The last is perhaps not an important point, as no marked differences between varieties are likely to be found.

Calyx Segments. — After describing the calyx as a whole we consider the individual segments, — their size, *small*, *medium* or *large;* their form, whether *obtuse, acute* or *acuminate;* and finally their position, whether *connivent, convergent* or *reflexed.* In some varieties, especially in over-developed specimens, they are *separate* at the base.

Tube. — The description of the calyx completes the exterior of the apple, and we come next to the interior, considering first the morphological characters exhibited. The tube length may be *short, medium* or *long,* the breadth *wide, medium* or *narrow,* and the form *conic* or *funnel-form.* The last term is an awkward one, but we can suggest none more suitable. The stamens are *basal, median* or *marginal,* according to whether they are near the inner end of the tube, in the middle or near the outer end. In describing the position of the stamens, only the broad or outer portion of the tube is considered; the narrower inner portion, which makes the tube funnel-form, should not be considered. Thus, "stamen position basal" means near the base or narrow end of a conic tube or of the broad portion of a funnel-form tube. The fleshy base of the pistils often persists, especially in specimens not thoroughly matured, and is noted as *present* or *absent.*

Core. — There seems to be some uncertainty as to the exact meaning of the term "core" as used by different systematic pomologists. We prefer to use it to indicate that portion of the fruit within the core lines. The first space in the blank shown is to describe the relation of the core to the axis of the fruit. If there is no space along the axis, and the axial border of the cells is straight, the core is said to be *axile,* while if the axial border of the cells is curved, so as to leave an oval or spindle-shaped space, the core is said to be *abaxile.*

Next is stated the size of the core relative to the size of the whole fruit, as *small, medium* or *large,* and then the position, — *sessile* if near the stem end of the fruit, *median* if in the middle, and *distant* if near the blossom end. The form of the core, as indicated by the course of the core lines, usually follows closely the outline of the fruit as a whole, and may be *oblate, oval, roundish, ovate* or *oblong.* Under "core lines" is described their relation to the calyx tube, which may be, rarely, *distant,* more commonly *meeting* or *clasping.*

Cells. — The cells are usually five in number, and the first point considered is whether they have an opening on the side toward the axis of the fruit; if so, they are *open;* if not, they are *closed.* Their size should be considered in relation to the size of the core as above defined, and they may be *small, medium* or *large.* If they are of similar size and form they are *symmetrical,* and if not, *unsymmetrical.*

Carpels. — The term "cells" signifies the space enclosed by the carpels, while the latter term means the horny walls, and each carpel is to be considered as a modified leaf. The form of the carpels is likely to be related to that of the core and of the whole fruit. They may be *elliptical, oblong, ovate, cordate, roundish* or *obovate.* The apex calls for especial consideration, and may be *acute, obtuse, mucronate* or *emarginate.* The surface toward the cell may be unbroken or *entire;* it may be marked by transverse fissures or *slit;* or these slits may be covered with a velvety growth, in which case the carpels are said to be *tufted.* The concavity of the halves of the carpels may be *little*, giving a small, thin cell, or it may be *medium* or *great.*

Seeds. — The number of the seeds may be stated as *few*, *medium* or *many*, and it is always desirable in careful work to give the exact number of seeds. Their condition may be *plump*, *medium* or *shriveled*, and their size *small*, *medium* or *large.* Size of seeds should be considered independent of the size of the fruit, and, as elsewhere stated, if the dimensions, preferably in millimeters, are given, it will contribute to the definiteness of the work.

The color of the seeds should be taken only from thoroughly ripe seeds, and is usually some shade of *brown*, *olive* or *gray.* The cross section, taken through the largest part of the seed, may be *roundish*, *oval* or *flattened*, while the longitudinal section, taken flatwise of the seed, may be *long* or *short;* also it may be *obtuse*, *acute* or *acuminate.*

Axis. — Axis length is considered in its relation to the size of the apple, and therefore is related to form and the depths of the cavity and basin. It may be *long*, *medium* or *short.* The direction is usually *straight*, but occasionally, and usually in the York Imperial, we find the axis *inclined.*

Flesh. — The flesh color is commonly *white* tinged more or less with *yellowish* or *greenish*, and it may be stained in certain parts with *pink* or *crimson.* The texture of the flesh is a very important factor, and may be described as *fine*, *medium* or *coarse;* also as *buttery*, *melting*, *breaking*, *crisp* or *firm*, the terms being arranged in order. A buttery texture is found only in those apples that break up and dissolve most readily in the mouth, while those with a very firm texture are usually not thoroughly ripened and break up only with some difficulty.

The juiciness of the fruit deserves special mention. It may be *little*, *medium* or *much.* It may be well to state that juiciness has no relation to the amount of water in the fruit.

Flavor. — Flavor and quality should be sharply differentiated, the former being due largely if not entirely to the relative proportions of sugars, acid and flavoring oils contained in the apple. It may be *acid*, *subacid*, *sweet*, according to the ratio of sugars and acid. The presence of an abundance of flavoring oil lends the quality often described as aromatic, but as aromatic relates to odor we prefer to use the word *spicy*, together with appropriate modifying adverbs, where the presence of flavoring oils is evident.

Aroma. — The aroma of an apple is often a means of identification, and it may be described as *none*, *faint* or *distinct.* If present it may be further described as *pleasant*, or special terms may be devised to suit the peculiar need.

Quality. — The term "quality" is used with a variety of meanings. In this bulletin it is meant to express the summation of the desirability of the apple for human consumption for table or kitchen use, as the case may be. Furthermore, it is the expression of the personal opinion of the individual describing it, and therefore it varies with different persons. There is no fixed standard for describing quality, and one person's opinion is as good as another's, provided his experience is as wide and his judgment equally sound. Quality is described as *poor*, *medium*, *good*, *very good*, *excellent* and *best*. The judgment of pomologists has been so charitable that "good" has come to signify that the apple under consideration is really rather poor and hardly desirable from the standpoint of quality; the other descriptive terms are similarly reduced from the meaning they have in common parlance.

In most cases one will hardly care to make such extended and minute descriptions as contemplated in the outline discussed above. Where a briefer description is sufficient, and for the student who has mastered these details, a briefer outline may readily be prepared; such briefer description will usually give for each variety those qualities which are characteristic and distinctive of that variety.

The Use of Quantitative Terms.

Where one wishes to do exact work it will increase accuracy to make liberal use of exact measurements; for the novice, especially if he be a student in systematic pomology, it will improve the soundness of his judgment in description, and therefore add to the value of his course of instruction. It takes time and cannot always be undertaken.

Many measurements of the tree characters may be made without difficulty. The height and spread of the tree may be ascertained by direct measurement if the tree is small, or by any of the usual methods of forestry work where the tree is large. The length and diameter of the shoots and buds are easily measured; also the length of the petiole and the length and breadth of the leaf blade. The size of the serratures is most conveniently measured by counting the number per half inch or per centimeter.

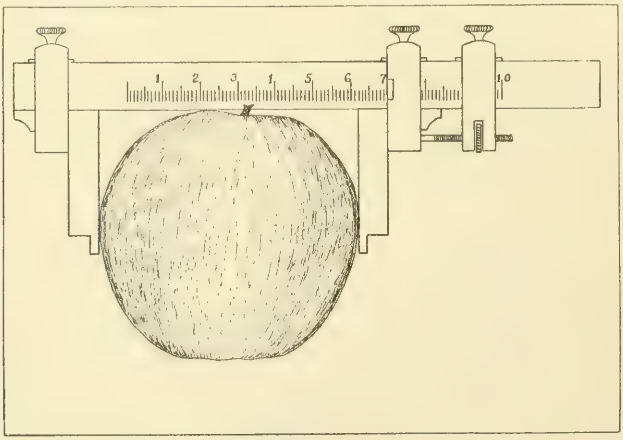

FIG. 3. — Measuring cross diameter.

An apple fruit seems rather an awkward body to measure accurately; nevertheless, by the adoption of certain fixed rules much can be accomplished. The instruments needed may be a simple ruler, preferably of celluloid, but a pair of calipers is often useful. The unit of measure may be the millimeter or the inch. In itself the former is much to be preferred, but the latter is more commonly used among American pomologists, and doubtless to them conveys a more definite meaning.

The most common and useful measures are the cross and axial diameters. The former should always be taken at right angles to the axis, and the latter parallel with it, and for the sake of a uniform practice it is best to secure the greatest diameter in each case. Calipers are necessary for exact work, but close approximations may be secured by placing the apple between two parallel surfaces, such as stiff cardboard or a pane of glass and a smooth table top. Of course, if the apple may be cut longitudinally the diameter may be quickly ascertained with a ruler. Care should be taken to cut so as to give its diameters at their longest.

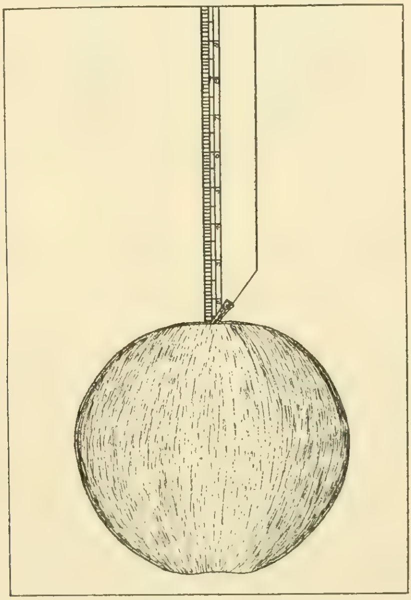

FIG. 4. — Measuring cavity depth.

The depth and breadth of the cavity and basin may be measured without cutting the fruit, as shown in Figs. 4 and 5. The rule should be whittled to a dull point about 2 millimeters broad, and the depth ascertained by sighting across the base or apex of the apple, as the case may be. In measuring the breadth the distance between the points of contact of the rule and surface of the fruit is taken. In both cases it is best to take the measure in the deepest and broadest part of the cavity or basin.

There are several characters in the interior of the apple that lend themselves readily to exact measurement. The length and breadth of the tube and of the core, as defined in the text, may be easily measured on cutting the apple longitudinally through the axis; also the length and breadth of the cells, making sure that the cut is made so as to split the cell exactly. The seeds are readily measured, giving their length, breadth and possibly thickness. The axis length from the insertion of the stem to the pistil point is easily measured.

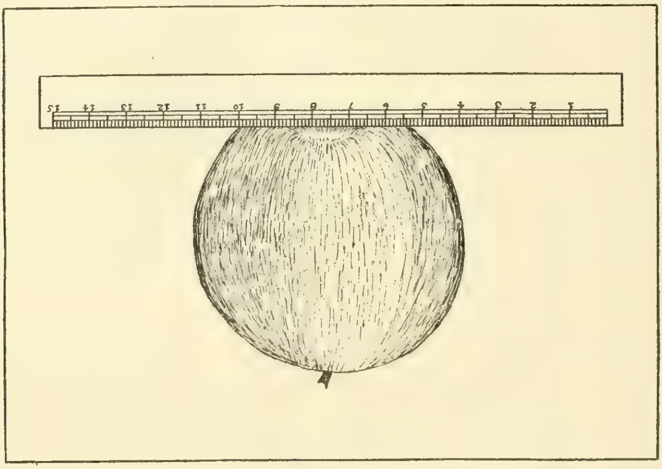
FIG. 5. — Measuring basin width.

THE COMMERCIAL DESCRIPTION.

A commercial description is quite a different thing from a systematic description. Many systematic characters are included, but their relative importance is changed, and many not mentioned in a systematic description are of the utmost importance. A commercial description of a variety can be made only after a long study of its behavior under varying conditions. Indeed, it would not be too much to say that we possess the knowledge needed for a fairly satisfactory commercial description of only a few varieties, and of these few there is much yet to be learned. Inasmuch as trade conditions are constantly changing, so must the commercial description be amended from time to time.

On the opposite page a blank for making a commercial description is suggested. The size, form and vigor of the tree are to be described as in the case of a systematic description. Under "diseases" should be mentioned such diseases as the variety in either tree or fruit is especially susceptible or resistant to, and so far as possible the degree of susceptibility or resistance. The same applies to the relation of the variety to various insects.

Variety

TREE

Size Form

Vigor

Diseases

Insects

Climatic adaptations

Soil adaptations

Cultural methods

Productiveness, earliness regularity

amount

Nursery growth

FRUIT

Size uniformity

Form uniformity

Color over-color

disposition amount

Skin Cells

Flesh, color texture juice

Flavor Aroma

Quality

Keeping quality Shipping quality

Market value

Remarks

Described by Date

Massachusetts Experiment Station Department of Pomology

FIG. 6. — Blank for commercial description.

Under climatic adaptations we may indicate the conditions of climate under which the variety succeeds best, or, what is simpler, name the region where the variety flourishes best and attains its highest excellence. Under "soil adaptations" should be given the type of soil and subsoil which offers conditions for the best development of the variety.

Comparatively little has been said about the different methods of cultural treatment suited to different varieties; we are not yet beyond argument over soil treatment for all varieties collectively. Yet who can doubt that varieties differ in this as well as in other respects, and that the ideal cultural treatment for one variety may be quite wrong for another sort. Space for this discussion is provided in the blank, and with the accumulation of knowledge along this line it should find expression therein.

The productiveness of a variety is most important, and space is provided for stating if the variety comes into bearing *early* or *late*, and if possible, the age at which it may be expected to begin to bear commercial crops. Under "regularity" is stated whether it is *annual*, *biennial* or *irregular* in its bearing habit, and under "amount," whether it is a *shy*, *light*, *medium*, *heavy* or *very heavy* bearer. Productiveness, as well as the characters of the fruit given later, depends greatly on the conditions of growth under which the trees find themselves. If we are making a generalized commercial description, it is supposed that the description given is for the variety when growing under conditions of climate, soil and culture favorable to its complete and most satisfactory development. Under nursery growth is given any marked characteristics of the variety as it grows in the nursery row. The behavior of a variety in the nursery has often been the determining factor in its success or failure. Under fruit the various characters are to be described in practically the same way as in the case of a systematic description, but only those characters that are of marked commercial value find space here. We have added the characters of keeping and shipping quality which may be appropriately described.

The market value of a variety is the final test of its commercial worth. Here should be stated the suitability of the variety to the local or general market, and if the latter, the attitude of the great markets of the world toward the variety should find mention.

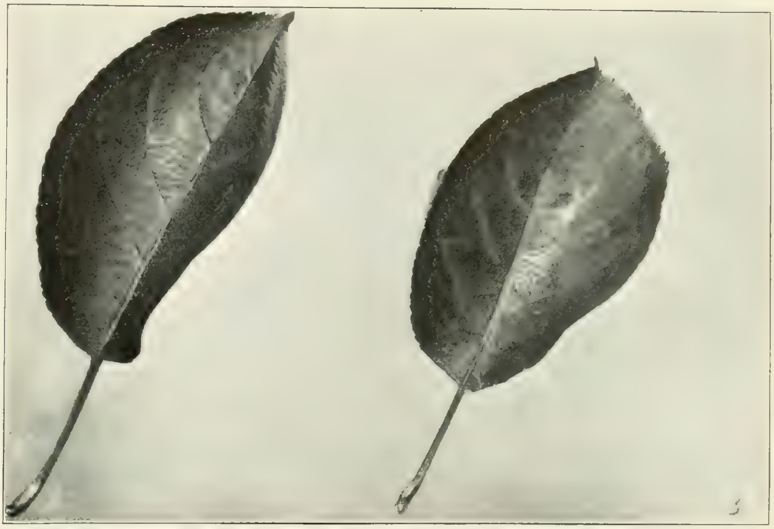

Fig. 7. — Baldwin × ⅔. Folded, even, straight or slightly reflexed, rather sharply serrate; the serratures strongly forward, often curved, medium size, generally rather deep, not distinct. The peculiar boat-shaped folding and curved, close-set serratures serve usually to identify the Baldwin.

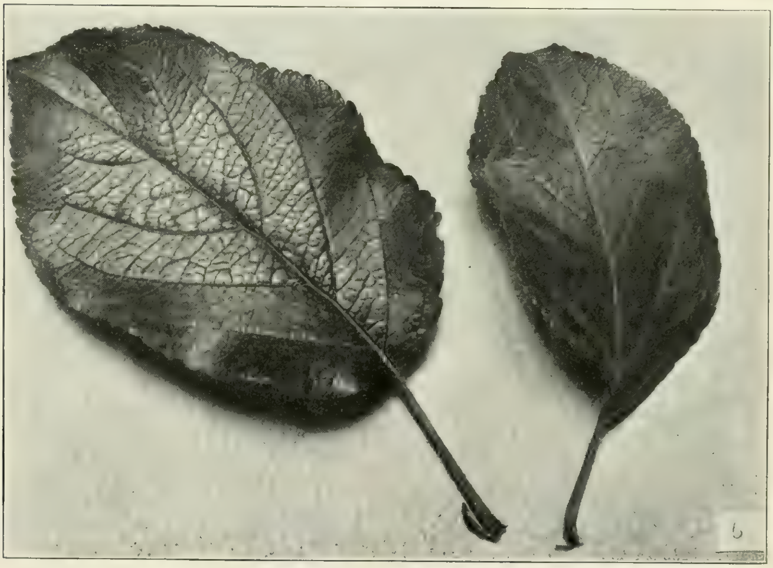

Fig. 8. — Wealthy × ⅔. Slightly folded, slightly reflexed and waved. Very dull serrate or crenate; serratures forward, rather small, medium regular, not curved. The Wealthy is distinguished by its waved leaf, dull serratures and rather coarse texture.

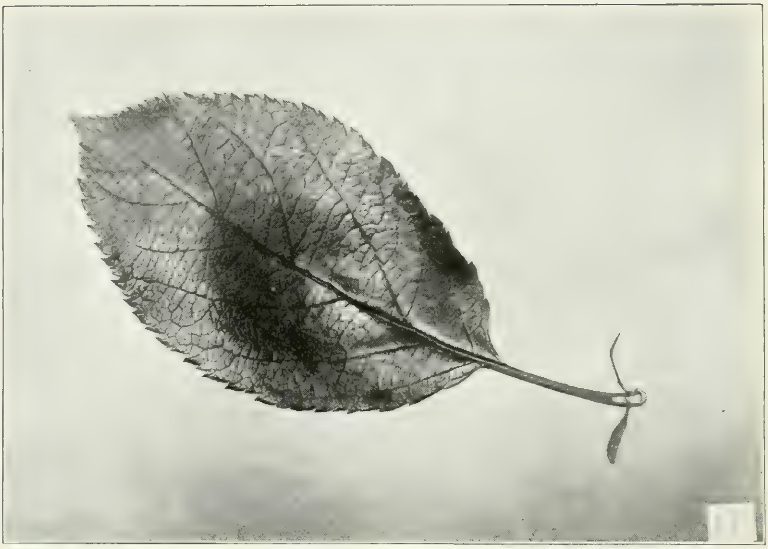

FIG. 9. — Rhode Island Greening × ⅔. Flat, straight or reverse curved, almost even, sharply serrate; serratures well forward, large, irregular, often tending to doubleness, not curved, deep and distinct. The sharp, distinct serratures are useful in identifying this variety.

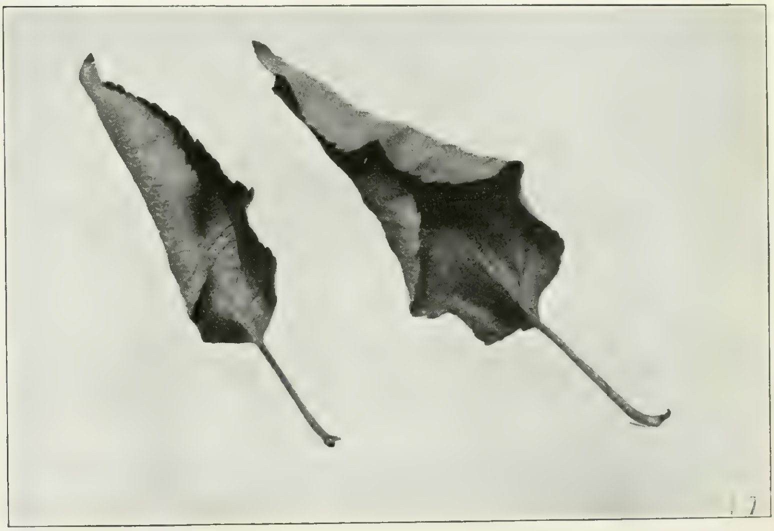

FIG. 10. — Jonathan × ⅔. Very small, strongly folded, sometimes reflexed, waved, dull serrate; serratures well forward, medium or rather small; irregular, often curved, shallow, rather indistinct. The small size, dull serrations, soft texture and strong folding serve to distinguish the Jonathan.

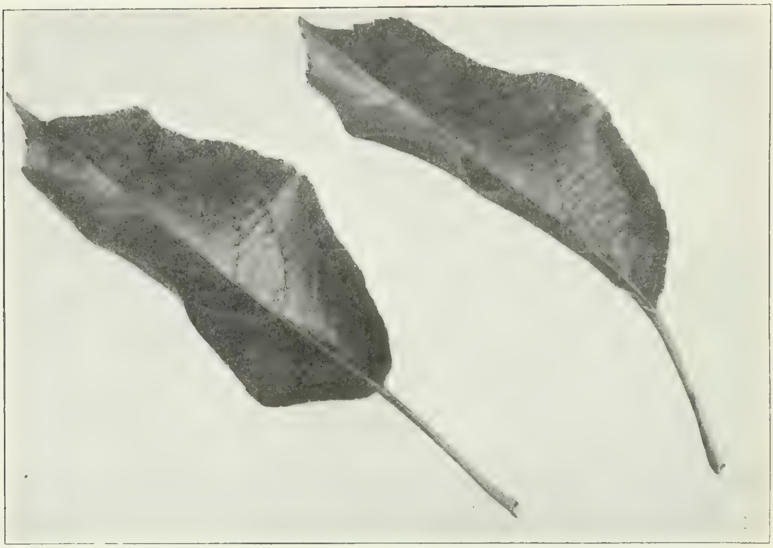

Fig. 11. — Ben Davis × ⅔. Small, folded, somewhat reflexed, waved, dull serrate or crenate; base narrow; serratures moderately forward, small, quite regular, somewhat curved, shallow. Ben Davis may be known by its distinct waving, narrow base and dull, shallow serratures.

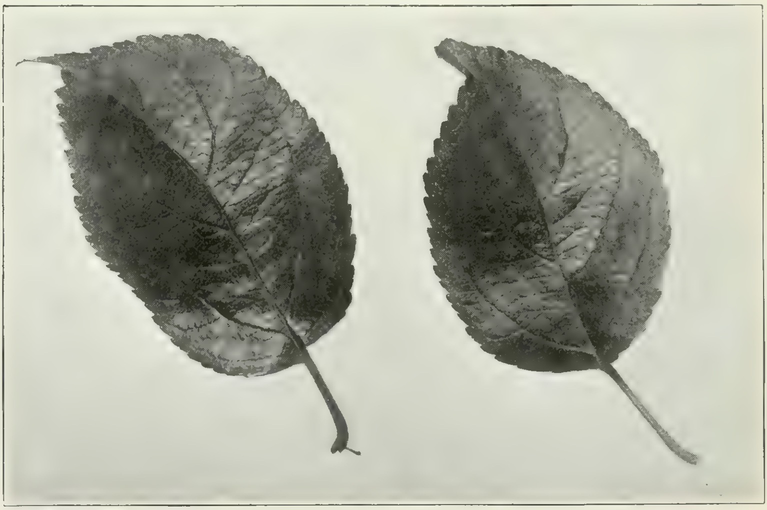

Fig. 12. — York Imperial × ⅔. Medium size, partly folded, reflexed, nearly even, dull serrate; serratures forward, large, irregular, rather deep, quite distinct. York Imperial may be known by its peculiar dull serrate, partly folded, spreading leaves.

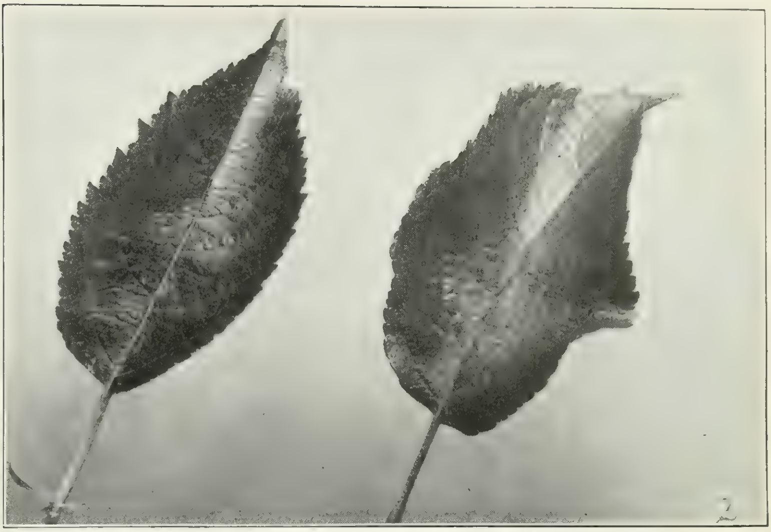

Fig. 13. — Hubbardston × ⅔. Small, folded, strongly reflexed, somewhat waved, dull serrate; serratures slightly forward, rather small, fairly regular, moderately deep, distinct. Hubbardston leaves may be known by their small size, peculiar dull serratures, folding, strong reflexion of the midrib and peculiar gray color.

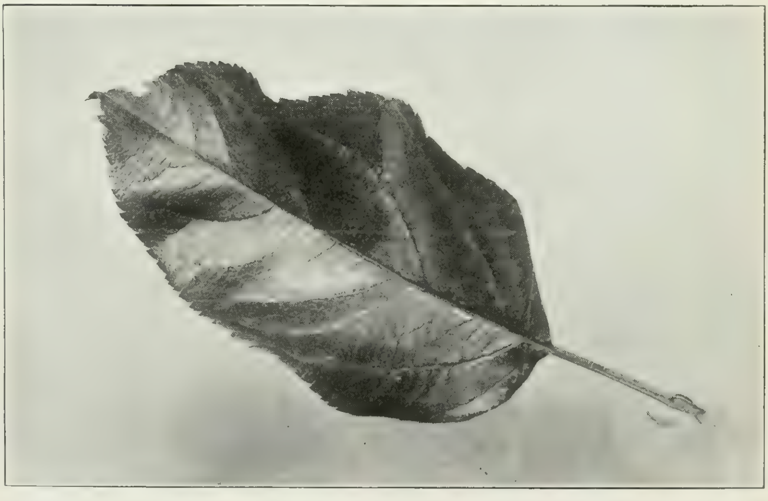

Fig. 14. — Northern Spy × ⅔. Partly folded, slightly reflexed, waved, serrate. Serratures well forward, medium or below, fairly regular, slightly curved, rather shallow, quite distinct. Northern Spy leaves not are easy to distinguish from several related varieties. Their peculiar folding, rather sharp serration and narrow apex serve to distinguish them from most varieties.

BULLETIN No. 160 APRIL, 1915

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

REPORT OF CRANBERRY SUBSTATION FOR 1914

By H. J. FRANKLIN

This bulletin contains a full report on the work at the cranberry substation in Wareham for the year 1914. It presents conclusions on many important points, among which some of the more prominent are: frost protection, prevention of fungous diseases, effect of spraying upon the keeping qualities of the fruit, effects of spraying upon the root development of the vines, results of fertilizer experiments, the effects of resanding, and methods of destroying injurious insects. Numerous new observations and discoveries concerning injurious insects are presented, together with important observations on the work of parasites on injurious insects, one of them not previously described. Observations on the movement of water in the peat of the cranberry bog, as well as on the root development of the cranberry, are presented, and the suggestion is made that some of the highly improved types of blueberries may be cultivated upon a commercial scale with greater profit than cranberries on bogs not provided with water for flowage.

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[1] On leave.

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Approved by
The State Board of Publication.

REPORT OF CRANBERRY SUBSTATION FOR 1914.

BY H. J. FRANKLIN.

The year's investigations have been along lines previously followed, except that the work with bees was discontinued and studies of the seasonal development of the cranberry root system and of the passage of water through peat were begun.

Weather Observations.

Records of conditions at the station bog were made as in previous years, and minimum temperatures at other locations were also recorded, together with whatever scattering data seemed to be of interest. The readings of the maximum and minimum shelter and bog thermometers and the amounts of precipitation were telegraphed to the office of the United States Weather Bureau at Boston during the periods of frost danger. Thermometers for taking soil temperatures were obtained, and records of those temperatures and their changes under different conditions were begun. The cranberry growing season as a whole was a cool one, there being more frost than usual, especially in September, and also much cloudiness throughout the summer. This caused the crop to ripen fully two weeks later than usual.

The total precipitation was distinctly below normal in spite of the unusual amount of cloudiness, and the beginning of the frost period in September found the ground rather unusually dry. The first cold night came on September 9, and was followed by nine others in succession. On some of these nights the minimum temperature at the low land thermometer near the station bog was 22° below the early evening dew point. Never before, by several degrees, had the station records shown any such difference under such general weather conditions. In the opinion of the writer, this extremely low temperature in comparison with the dew point was due mainly to an unusual lack of moisture in the ground. The difference between the minimum readings of thermometers on the station bog and on low land immediately adjacent was only 2° on the night of the 9th, and there was no difference the following night (10th). The temperatures were not compared on the 11th and 12th, the bog being flooded. On the 13th, the low land ran 6° colder than the bog minimum. As the bog was flooded again on the 14th, the next comparison was made on the 15th, when there was found to be a difference of 5½°. Never before in the records of four seasons had there appeared such a difference in the minimum temperature of these two locations unless the bog was flooded, — a fact which seemed to require explanation. As this difference did not occur until after the bog had been reflowed (no reflowing whatever had been done between June 26 and September 11), it seems probable that the effect of the flooding partially remained with the bog in some way in nights following those in which the flowing was done. Before the flooding, both the sand of the bog and the adjacent low land were unusually dry. The flooding left the bog in a condition of normal moisture, while the low land remained abnormally dry. This was apparently all that could have had any effect on the difference in temperature between the two locations. It seems evident, therefore, that moisture in the soil tends to maintain a higher air temperature above it on cold nights than would be had without it. That this is true is borne out further by the records of the latter part of September and the first part of October. On the 16th, the difference in the minimum temperature of the two locations — above mentioned — was 4½°; on the 17th, 3° (possibly so little because of failure of one thermometer to record properly); on the 18th, 4°; on the 20th, 6°; and on the 30th, 5°, these dates being selected because their nights alone were cold. Before any October records were made, over half an inch of rain fell, which, of course, did much to bring the soil of the low land back to a normally moist condition. After this rainfall the difference in the minimum temperature between the bog and the low land ranged from 1½° to 3½°, being distinctly less than it was before the rain came.

Acting on the suggestion obtained from these observations, that an increased water content of the soil tends to raise the minimum air temperatures above it on cold nights, the writer had two circular grassy areas (of between 2 and 3 square rods each) covered to an average depth of 6 inches with as dry sand as could be obtained in any quantity, between September 20 and 25. A Green minimum thermometer was placed over the center of each of these areas. On the nights of both September 26 and 27, these thermometers showed a difference of half a degree in their minimum readings. On September 28, the spot which had showed the lower minimum temperature on the two previous nights was wet down thoroughly with water, the wetting being done between 10 A.M. and 2 P.M., the temperature of the water used being 51° (pumped from a driven well 22 feet deep) and that of the sand on the other spot ranging from 51° to 52° at noon. The temperature of the air 6 inches above the center of the spot not wet down was 52° at 11 A.M., and that of the water in the ditches of the station bog at the same time ranged from 53° to 55°. In the cold nights following soon after, the thermometer over the spot that had been wet down recorded a minimum temperature from half a degree to a degree higher than the other one, the result of the test thus corresponding in a general way to that of the observations in connection with the bog and low land thermometers. Great reliance, however, cannot be placed on this result because of the small size of these test areas.

While the results of this investigation are not conclusive, they raise a question of no little importance, for if the moisture content of a soil affects the minimum temperatures of the air above it to any considerable extent, it is a factor that should be considered in making frost predictions in connection with the growing of cranberries and possibly of other crops also. It should be noted, however, that the results here discussed are at variance with those obtained by Prof. H. J. Cox on the Wisconsin marshes ("Frost and Temperature Conditions in the Cranberry Marshes of Wisconsin," by Henry J. Cox, 1910, Bulletin T. of the Weather Bureau, United States Department of Agriculture, page 61). Professor Cox shows that in comparative studies he obtained the lower temperature readings over the soil containing the greater amount of moisture and states that the increased moisture was "solely responsible for the relative low temperature readings, on account of the heat lost in the evaporation of the surface." The greater specific heat of water, as compared with dry earth, should not, however, be lost sight of in considering this matter.

Frost Protection.

Experiments with cloth, such as is used in growing tobacco under shade, were carried out in September, to see if it could be used satisfactorily in protecting bogs from frost. In these tests a strip of new cloth was supported by wires held 3 feet above the ground by stakes, about 9 square rods of rather dry, grassy low land being covered in this way, the cloth being brought down to the ground to shut in the covered area on all sides. The cloth was spread out for the tests after sundown on cold nights, and was always removed soon after sunrise, so that the ground might be normally exposed to the heat of the sun during the day. Considering the very coarse weave of the cloth, it retarded the rise of heat from the ground to a surprising extent, evidently because the heavy dew that accumulated on it closed its openings considerably. A Green minimum thermometer was placed at the center of the covered area, with its bulb 5 inches above the grass-covered ground, and a similar thermometer at the same elevation, located over grass about 20 feet outside of the cloth, was used for comparison. No frost formed on the covered ground during the tests even when the surrounding low land was white with it, and the thermometers showed that the cloth gave an advantage of more than 4½° in temperature, as shown by the readings in the following table: —

TABLE 1. — *Effect of Cloth Cover on Temperature.*

Date.	Minimum Temperature (Degrees Fahrenheit).		Wind Velocity (Miles per Hour).
	Area 1.	Area 2.	
September 13, ...	Covered, 31, . .	Not covered, 26½, .	1½ to 4
September 14, ...	Covered, 31, . .	Not covered, 26½, .	6/7 to 1
September 15, ...	Covered, 30⅔, . .	Not covered, 26½, .	⅗ to 1 5/7
September 16, ...	Not covered, 29¾, .	Not covered, 30½, .	No record.
September 17, ...	Not covered, 32⅓, .	Not covered, 32¼,[1] .	No record.

---

[1] This reading was unusually high, as compared with that over "Area 1," as was shown by numerous readings of these thermometers observed later, but not recorded.

The difference in temperature caused by the use of the cloth might have been greater had a larger area been covered, but the advantage shown in the table would be sufficient to entirely protect a bog in most locations, except under such extreme conditions as would only rarely occur, and even under such conditions it would afford a partial protection. The results of the tests, therefore, appear to highly recommend the use of this cloth for frost protection on bogs which are winter flowed but cannot be reflowed in any way at reasonable expense. It can be purchased in quantity from the manufacturers, all sewed up in strips of any desired size, for 3⅛ cents per square yard, the cost of enough for a whole acre being only about $150, and, if properly cared for, it ought to give good service for many years, as it would seldom be used for extended periods. When used to cover a whole bog, it would have to be spread out on wires in sections and be so arranged that considerable areas could be either covered or uncovered by a single pull of a rope. The first cost of this means of protection fully installed probably would be less than $200 an acre, and the loss by depreciation would be no greater than the cost of the upkeep and operation of a pumping plant. If a grower had to install his protection at less cost than this, he probably could do so by buying cloth that had been used one season in growing tobacco. In the opinion of the writer, the protection afforded by new cloth would be as good as that which would be had with a pumping plant, for such plants frequently fail in emergencies. For strictly dry bogs (without winter flowage) the expense of cloth protection seems prohibitive, because the returns from such bogs are comparatively small.

Fungous Diseases.

These studies were carried on, as in former years, in co-operation with the Bureau of Plant Industry of the United States Department of Agriculture, Dr. Shear having general supervision of the spraying experiments and conducting the laboratory investigations.

Of the various sprayed plots, results with which have been given in previous reports, the following were treated again with Bordeaux mixture on dates as indicated, the neutral copper acetate application given in former years being omitted: A, three times, on June 16, July 20 and August 7; B, three times, on June 16, July 20 and August 8; D, three times, on June 13, July 20 and August 13; "1913," three times, on June 16, July 27 and August 17 (an extra spraying was applied during full bloom to one-half of this plot on July 11); one-half of fertilizer plot 15, three times, on June 16, July 20 and August 8. Plots C and E were left without treatment. The middle half of plot A was fertilized on June 18, a quarter of the plot on each side being left without fertilizer as in the previous season, that used on the middle portion being applied at the following rate per acre: —

	Pounds.
Nitrate of soda,	200
Acid phosphate,	400
High-grade sulfate of potash,	200

The following table shows the total amount of fruit picked from these various plots and from check areas measured out on the bog adjacent to them, as well as the rate of yield per rod in each case, the relative size of the berries, and the per cent. of increase or decrease in fruit production of the plots as compared with their checks: —

TABLE 2. — *Results of Spraying for Fungous Diseases.*

PLOT.	Area of Plot (Square Rods).	Variety.	Date picked.	Quantity of Fruit obtained (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Decrease or Increase on Plots (Per Cent.).	Average Size of Berries and Number of Samples examined.
A (middle portion), .	8	Late Howe, .	Sept. 26	9	1.125	23.5[1]	90+3 (6)[2]
A (side strips), .	8	Late Howe, .	Sept. 26	9⅔	1.208	17.8[1]	96+4 (10)
A (3 checks),[3] . .	17½	Late Howe, .	Sept. 26	25⅔	1.470	–	94+4 (5)
B, ...	14⅛	McFarlin, .	Sept. 26	11½	.814	3.2[1]	72+2 (6)
B (1 check), . .	13⅔	McFarlin, .	Sept. 26	11½	.841	–	67+2 (6)
C, ...	16	Late Howe, .	Sept. 26	11⅔	.729	13.2[4]	97+4 (6)
C (2 checks), . .	9	Late Howe, .	Sept. 26	5⅘	.644	–	95+3 (6)
D, ...	16	Early Black, .	Sept. 16	14⅔	.917	3.85[4]	109+11 (6)
D (2 checks), . .	16½	Early Black, .	Sept. 16	14½	.883	–	103+8 (6)
E, ...	16	Early Black, .	Sept. 8	9	.563	10.9[1]	106+11 (6)
E (2 checks), . .	12	Early Black, .	Sept. 8	7 7/12	.632	–	103+5 (6)
"1913,"[5] . . .	4½	Late Howe, .	Sept. 26	5½	1.222	38.39[4]	100+4 (6)
	4½	Late Howe, .	Sept. 26	6⅓	1.407	59.34[4]	100+5 (6)
"1913" (2 checks), .	6	Late Howe, .	Sept. 26	5 3/10	.883	–	100+3 (6)
Sprayed half of fertilizer plot 15, . .	4	Early Black, .	Sept. 16	5⅙	1.292	1.6[1]	104+8 (6)
Other half of plot 15,	4	Early Black, .	Sept. 16	5¼	1.312	–	106+6 (6)

---

[1] Decrease.

[2] The size of the fruit as shown in the above table was worked out by taking counts of the berries in cupful samples (New England Cranberry Sales Company's inspector's cup), the samples being spread out in a sales company's inspector's hand-grader before the counting was done. When placed in the grader the smallest berries would pass through into the box below, leaving the larger ones to be counted separately. In such formulas as "90+3," given in the table, the first figure shows the average number of large berries, and the second indicates the number of small ones that passed through the grader, the figure in parentheses being the number of samples examined. These samples were examined at the end of the storage tests, and were taken from different boxes as far as possible, so that they might fairly represent the areas from which the berries were picked.

[3] When two or more checks were taken on a plot, as the table shows was generally the case, they were laid out on opposite sides of the plot, and their areas and fruit production were combined in making up the table.

[4] Increase.

[5] The first record given for this plot is for the half sprayed in full bloom, and the other record is for the half which received the three other applications only.

It will be seen at once that, of all these plots, "1913" alone showed a marked increase in the quantity of fruit produced. This plot was sprayed for the first time in 1913, and the results obtained with it in this second year of spraying agree, in a general way, with those obtained in 1912 with plots A, B, C, D and E, they then having been sprayed only one year before. Moreover, the increase was marked, though considerably reduced, even on that portion of the plot which had been sprayed during full bloom. The reason for this increase in the second year of spraying is obscure, but the fact that it takes place is interesting. The fact that the sprayed half of fertilizer plot 15, which was also sprayed for the first time in 1913, did not show an increase in fruit production is contradictory, but the fertilizer used on this plot may have made the difference.

All the other plots treated this year, except D, produced less fruit than their checks, and D showed only a slight increase. The untreated plot C produced distinctly more fruit than its checks, while E showed a decrease almost as great; the results with these two plots thus being contradictory and not sufficiently marked to be of any apparent value. As all the plots produced much less fruit in 1913 than did the surrounding portions of the bog, they should all, under normal conditions, have shown a distinct increase in 1914 because of their partial rest from fruiting. That they did not do so is good evidence that the spraying was not particularly beneficial and perhaps indicates injury from it.

The smaller the berries the greater the number it took to fill the cup, and if the table is examined with this in mind it will be seen that all of the plots, except "1913," the sprayed half of fertilizer plot 15 and the middle portion of plot A, produced distinctly smaller berries than did their checks. The fertilizer accounts for the exception with plot A and probably also with plot 15; "1913," as already indicated, was an exceptional plot because of its having been sprayed only one season before 1914. The size as well as the quantity of the fruit on these plots seems, therefore, to indicate that general spraying is not a good practice.

The spraying on all these plots was done with a 30-gallon wheeled-barrel outfit, the mechanical injury to the vines not being very great as a long hose was used and the outfit was in no case taken onto either the sprayed areas or their checks. The berries were all picked with scoops and measured in selected boxes of approximately the same size, the loose vines being carefully removed by hand.

The keeping qualities of the fruit from these plots and their checks were tested, the period of storage extending from November 3 to December 30 with the late berries, and from November 14 to New Year's with the Early Blacks. As in the 1913 tests, the berries were carefully measured in every case. The results of these tests were not definite enough in any respect to be satisfactory, perhaps because they were begun too late or because the berries were run through a separator before they were placed in storage, this not having been done in previous years.

As already indicated, one-half of plot "1913" was sprayed during full bloom to determine whether Bordeaux mixture, made according to Dr. Shear's formula for its preparation for cranberry spraying, would do serious damage if applied at that time. The figures given in Table 2 show that this spraying did injure the blossom considerably, causing a reduction in the crop of about 13 per cent., if we regard the bloom as having been equally abundant on both halves of the plot. As a matter of fact, however, the more heavily blossomed half was purposely selected for this special spraying, and the reduction caused by it, while not definitely computable, was certainly much greater than the figures show.

Tests of the possibility of controlling fungous diseases by putting copper-sulfate in the flowage were again carried out this year, a solution of the chemical being used in the June reflow on flooding sections 23, 25 and 27 at the rate of 1 part to 50,000 parts of water (1 pound in 6,250 gallons). The treatment was applied after these sections had been completely flooded for seventeen hours, and the water was then held twenty-six hours longer. The sulfate solution was thrown into the water by the cupful and was distributed as evenly as possible over all parts of each section treated. The date of treatment was June 11. The blossom buds were then well developed and they did not seem to be injured by the treatment.

Both the treated and untreated sections were picked with scoops on September 7, the former showing no definite advantage in the quantity of fruit obtained. In the storage tests, however, the berries from the treated sections showed, in every case, a distinctly smaller percentage of loss than did those from the other sections. These results are exhibited more in detail in the following table: —

TABLE 3. — *Effect of Treatment with Copper Sulfate in June Reflow.*

FLOODING SECTION.	Variety.	Area of Plot (Square Rods).	Quantity of Fruit picked (Bushels).	Quantity of Fruit per Square Rod. (Bushels).	Period of Storage.	Quantity stored (Bushels).	Loss in Storage (Per Cent.).
21, . .	Early Black,	21.30	13¼	.622	Nov. 14 to Jan. 1.	3	20.59
22, . .	Early Black,	5.10	2¾	.539	Nov. 14 to Jan. 1.	1	29.41
23,[1] . .	Early Black,	12.80	9⅓	.729	Nov. 14 to Jan. 2.	3	18.63
24, . .	Early Black,	5.00	3	.600	Nov. 14 to Jan. 1.	2	26.09
25,[1] . .	Early Black,	11.60	7⅓	.632	Nov. 14 to Dec. 30.	2	13.97
26, . .	Early Black,	4.50	2½	.555	Nov. 14 to Dec. 31.	1	34.00
27,[1] . .	Early Black,	10.66	7	.656	Nov. 14 to Dec. 31.	2	16.67
28, . .	Early Black,	3.08	1¼	.406	–	–	–
29, . .	Early Black,	10.61	8	.754	Nov. 14 to Dec. 31.	2	23.53

[1] Treated.

The reddened and sickly appearance of the foliage on most of the sprayed plots, mentioned in the report for 1913 (page 41), persisted more or less throughout the season of 1914, especially with the Late Howe plots, even where the spraying was discontinued this year. The reason for this apparent injury to the sprayed areas was carefully sought, the condition of the root systems of the sprayed and unsprayed vines being given particular study, as such an investigation seemed to promise the most ready solution of the problem. The roots were first examined late in May. It was soon found that new rootlets were developing in connection with the unsprayed vines all over the bog. On the sprayed plots, however, there was almost no new root development. It was also noticed early in the season that there was a rather scanty growth of old rootlets near the surface of the sand on the sprayed areas, while on untreated parts of the bog this growth was evidently much more abundant. Moreover, the rootlets near the surface on the plots appeared to be blackened and rather lifeless, as though injured by burning. In June and July the difference in the condition of the roots of the sprayed and unsprayed vines was rather striking. It could be most easily observed by grasping single vines between the thumb and forefinger, close to the surface of the sand, and pulling them up by the roots. When this was done, it was apparent at once that there was no considerable mass of rootlets on the sprayed vines for about an inch below the surface of the sand, while on those that had not been sprayed the rootlets were usually massed close up to the very surface. This condition of the roots seemed to suggest that they had been injured by the spraying in some way.

Attention is called, in this connection, to the fact that a New Jersey grower of large experience has informed the writer that he found his vines taking on a similar sickly, reddish appearance after he had been spraying his bog a few years. His vines apparently got into a worse condition than have those on the sprayed plots of the station bog, a considerable dying out taking place among them. The grower, however, laid the trouble to lack of proper plant nutrition, and applied fertilizers containing nitrates. His vines recovered, taking on a normal green appearance, and are now producing satisfactory crops again. His results in this regard seem to be paralleled — to a considerable extent — by those obtained on the station bog with plot A, the middle half of which was fertilized in both 1913 and 1914, as stated in another place. The vines remained green and thrifty on the fertilized part of this plot, while the unfertilized parts took on the reddened appearance that has been described. In both 1913 and 1914, however, the fertilized part of this plot failed to produce anywhere near as much fruit as did the surrounding unsprayed portions of the bog. While it is by no means certain that the New Jersey grower's difficulty was caused in the same way as that on the station bog, the comparison is certainly suggestive.

To get further light on this whole problem, and to determine definitely in what ways spraying with Bordeaux mixture does injury, special spraying experiments were started on small plots, the sprays applied being made up with varying proportions of lime and copper-sulfate, resin fish-oil soap being used with some and being left out with others. These sprays were applied in excessive quantities (25 gallons to the square rod) so that they would soak into the ground and come in contact with the roots thoroughly. If these experiments show that Bordeaux mixture necessarily causes considerable injury to cranberry bogs, general spraying for the control of fungous diseases on the Cape bogs will seem impracticable until some non-injurious substitute for the Bordeaux can be found. Doubtless, some bogs are occasionally so badly infested with fungous diseases that spraying would be advisable even if it did cause considerable injury. Diseases appear to be so much more prevalent in New Jersey than they are on the Cape bogs that spraying should probably be generally adopted there in spite of the possibilities of its doing damage.

The "ring-worm" trouble (commonly so-called by the growers because it was formerly supposed to be the result of some insect's work) was given some study. The vines die in a small patch at first and, the center recovering, the affected area gradually becomes circular. These patches persist for years, the vines on the outer side of the rim dying every season, while recovery takes place on its inner side, the circle thus growing larger yearly and preserving its form if not interfered with by a ditch or some other obstruction. Both Dr. Shear and the writer for some time have believed this trouble to be due to a fungous disease. Insects evidently do not cause it. This year evidence has come to hand which appears to go far toward proving that fungi are at the bottom of the trouble. On Sept. 24, 1910, the writer visited some bogs in Plymouth, belonging to Mr. Henry J. Thayer of Boston, and found them more badly marked with "ring-worm" patches than any other bog he has ever seen. Moreover, it had been with Mr. Thayer a trouble of long standing, for the "rings" varied in size from mere beginnings to circles 25 or 30 feet in diameter. He thought it was caused by some insect, but decided to try spraying with Bordeaux mixture on the chance that it might be a fungous trouble. He sprayed twice in 1911, three times in 1912, three times in 1913, and twice in the present year, before the writer visited his bogs again on July 4. The change since 1910 was very striking, the "rings" having in most cases entirely or nearly disappeared, and no new dying of the vines being apparent. Mr. Thayer thought his spraying had caused the improvement, and it evidently had. His results seem to help prove the character of the "ring-worm" trouble. It should be stated, however, that in all of his spraying after the season of 1911 Mr. Thayer used commercial "Bordo Lead" with a little Paris green instead of straight Bordeaux mixture.

Early in July, a North Carver grower sent in some vines seriously affected by an unfamiliar disease. Specimens were forwarded to Dr. Shear, and he found the trouble was one which had been known for a long time in Wisconsin, but which had never been previously reported from any other cranberry-growing section. The Wisconsin growers commonly call this disease "false-blossom." There is, however, an entirely different trouble known as "false-blossom" (hypertrophy caused by *Exobasidium* sp.) by the Cape Cod growers, and to distinguish between the two, the new disease will be called "Wisconsin false-blossom" in this report. It is characterized by an abnormally profuse branching of the vines and a peculiar abortion and malformation of the blossoms. The latter do not develop normally in size or color, but are small and greenish. The peduncles do not curve over naturally, but remain straight and become more or less swollen, so that the flowers open facing upward. The blossoms thus affected produce no berries, and the crop is often greatly reduced in quantity when the vines are badly infested.

The vines sent in affected with this trouble came from a bog on which "Metallic Bell" vines from Wisconsin were planted about ten years ago. The discovery of this disease in Carver led Dr. Shear and the writer to investigate its distribution. It was found on five bogs, all in North Carver, the source and center of trouble being evidently, in every case, vines which had come from Wisconsin. On four of these bogs the trouble centered around the "Metallic Bell" variety. The name of the variety causing the trouble in the fifth case is not known. On one bog the disease had apparently spread from the "Metallic Bell" vines and attacked those of the "Late Howe" variety, especially on some new planting, and was also found to some extent on "Nova Scotia Bell" vines. On another it seemed to have spread from the "Metallic Bell" variety to "Centreville" vines to a slight extent. It was least prevalent on the bogs which had usually been run dry during the growing season, those which had been kept wet being very badly infested. It was first observed on one of these bogs five years ago and has apparently been growing gradually and steadily worse. The discovery of the presence of this Wisconsin disease on the Cape may be a matter of much importance. It is evidently a serious disease, and the results of the season's observations strongly suggest that it may be infectious, though it has by no means been proved to be so. Until more is known about it, Wisconsin varieties cannot be planted on the Cape without considerable risk. The discovery of this disease in Massachusetts and the results of our investigation concerning it are especially interesting in the light of the observations regarding it recently published in the annual report of the director of the Wisconsin Agricultural Experiment Station.[1]

Observations in connection with the new disease, spoken of as the "blossom-end rot" in previous reports, have been continued. This disease was again this year the chief cause of decay among "Late Howe" berries in storage. Numerous samples of fruit infected with it were sent to Dr. Shear for laboratory investigation. Its exact place in botanical classification is not yet determined.

RESANDING.

The experiments in resanding have been continued, five plots on the station bog having been devoted to this investigation since October, 1912. Two of these plots have not been resanded for six years. The other three have been resanded every year for the last four years. The bog as a whole was resanded in the fall of 1911 and spring of 1912 and again in the fall of 1914.

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[1] Bulletin No. 240 of the Wisconsin Agricultural Experiment Station, June, 1914, p. 54.

The results with these plots in the amounts of fruit produced were not at all conclusive. The results of the storage tests, however, with only one exception, agreed with those of former years in showing that resanding greatly favors fungous diseases.

FERTILIZERS.

Most of the fertilizer plots on the station bog were given their 1914 application on June 17 and 18. The lime was not applied to plot 11 until July 17, and plot 12 went without fertilizer until the same date because the muriate of potash was not delivered promptly. The plots were picked with scoops on September 16 and 17, no distinct advantage in quantity of fruit being shown by the fertilized areas as compared with the check plots. The berries seemed so uniform in color and most other respects that no records were made except of their quantity and size. Average counts of berries in several cupful samples taken from each of the plots did not show that the fertilizer had distinctly affected their size.

Storage tests, beginning November 14 and ending on New Year's day, were carried out with berries from each of the plots. These tests probably were not as reliable as those of former years because the berries were run through a separator before they were stored. The results, however, seem to show that the nitrate of soda distinctly impaired the keeping quality, though the greater shrinkage of the fruit from the nitrate-treated plots may have been due to a greater loss of water during storage, rather than to increased rotting, the berries perhaps being somewhat more succulent. The year's experience with these plots and their fruit is shown in detail in Table 4.

Plots 1, 5, 9, 13, 17, 21, 22 and 23 are all untreated check plots. The meanings of the fertilizer symbols used in the table are as follows: —

O = Nothing.
N = 100 pounds nitrate of soda per acre.
P = 400 pounds acid phosphate per acre.
K = 200 pounds high-grade sulfate of potash per acre.
L = 1 ton of lime (slaked) per acre.
Kcl = 200 pounds muriate of potash per acre.
$N_{1\frac{1}{2}}$ = 150 pounds nitrate of soda per acre.
N_2 = 200 pounds nitrate of soda per acre.
$P_{1\frac{1}{2}}$ = 600 pounds acid phosphate per acre.
P_2 = 800 pounds acid phosphate per acre.

In combination they mean, for example, as follows: $N_2PK = 200$ pounds of nitrate of soda + 400 pounds of acid phosphate + 200 pounds of high-grade sulfate of potash per acre.

TABLE 4. — *Effect of Fertilizers on Quantity and Keeping Quality of Cranberries.*

PLOT.	Fertilizer used.	Date picked.	Quantity of Fruit produced (Bushels).	Quantity of Fruit in Storage Test (Bushels).	Loss in Storage (Per Cent.).
1,	O	Sept. 16	9	3	27.45
2,	N	Sept. 16	9½	3	31.37
3,	P	Sept. 16	8⅘	3	20.59
4,	K	Sept. 16	8	3	24.51
5,	O	Sept. 16	6½	3	26.96
6,	NP	Sept. 16	6⅔	3	34.00
7,	NK	Sept. 16	7⅔	3	31.37
8,	PK	Sept. 16	8⅔	3	23.53
9,	O	Sept. 16	6½	3	29.41
10,	NPK	Sept. 16	8⅔	3	33.00
11,	NPKL	Sept. 16	8⅙	3	37.25
12,	NPKcl	Sept. 16	7¾	3	28.43
13,	O	Sept. 16	7⅔	3	22.53
14,	$N_{1\frac{1}{2}}PK$	Sept. 16	10	3	24.51
15,	N_2PK	Sept. 16	10 5/12	3	26.96
16,	$NKP_{1\frac{1}{2}}$	Sept. 16	9	3	27.45
17,	O	Sept. 16	9⅔	3	23.04
18,	NKP_2	Sept. 17	10	3	30.39
19,	$NPK_{1\frac{1}{2}}$	Sept. 17	9	3	25.49
20,	NPK_2	Sept. 17	6⅚	3	31.37
21,	O	Sept. 17	10⅓	3	32.50
22,	O	Sept. 17	10⅘	–	–
23,	O	Sept. 16	6⅓	3	22.22

As some of the 1913 experiments had seemed to indicate that the setting of the blossoms was stimulated and increased to a considerable extent by the application of nitrogenous fertilizers during the beginning of the bloom, special tests to determine this point were conducted this year. Two plots of four square rods each — one "Early Black" and one "Late Howe" — were fertilized on July 3, the former variety being in full bloom and the latter needing about a week longer to reach that condition. The fertilizer was applied at the following rate per acre: 150 pounds of nitrate of soda + 400 pounds of acid phosphate + 200 pounds of high-grade sulfate of potash. The sand with which the fertilizer was mixed to insure even application stuck to the vines considerably, and it was feared that it might injure the bloom more or less, especially that of the more advanced early variety. The fertilizer was soaked into the bog by a storm which began at 6 P.M. on July 6, there having been no previous rainfall whatever since its application. The plots were examined on July 7, and the "Early Black" vines were then found to be somewhat past full bloom, those of the "Howe" variety having not yet quite reached that condition. Table 5 shows the results obtained with these plots. The size of the berries is indicated by the number it took in each case to fill the inspector's cup of the New England Cranberry Sales Company, two samples being averaged for the "Early Black" records and six for the "Late Howe." The smaller the berries the greater, of course, was the number it took to fill the cup, the sizes, therefore, being inversely proportional to the numbers given in the table: —

TABLE 5. — *Effect of Fertilizer on Setting of Fruit.*

PLOT.	Area of Plot (Square Rods).	Date picked.	Quantity of Fruit obtained (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Increase (Per Cent.).	Average Size of Berries and Number of Samples examined.
Early Black, . . .	4	Sept. 10	3¾	.937	7.14	125 (2)
Early Black (check), .	4	Sept. 10	3½	.875	–	120 (2)
Late Howe, . . .	4	Sept. 28	6⅘	1.700	26.50	103 (6)
Late Howe (check), . .	8	Sept. 28	10¾	1.344	–	106 (6)

As the table indicates, there was a distinct increase in fruit on the "Early Black" plot as compared with the surrounding bog, though it was much less marked than that on the "Late Howe" plot, probably because of the difference in the development of the bloom when the fertilizer was applied. It will be seen at once that the increase in quantity was in neither case due, to any considerable extent, to an increase in the size of the berries, and that the fertilizer had apparently caused a greater number of blossoms to set and form fruit with both varieties. In storage tests there was slightly more decay among the berries from the "Late Howe" plot than among those from its check. The "Early Black" fruit was not tested in this regard.

INSECTS.

The insect studies have covered a rather wide range during the year. The flowed-bog fireworm (black head cranberry worm) and the fruit worm both seem to have been much less abundant than usual, the total injury caused by them probably being about the same as in 1913.

In May and June the forest tent caterpillar (*Malacosoma disstria* Hübner) was very abundant everywhere in the cranberry section, and the worms crawled onto the bogs in large numbers. Their operations were watched carefully, but they were never found feeding on the cranberry vines, and their presence on the bogs need never cause concern, for their normal food plants are evidently so different from the cranberry that the latter is not palatable to them.

Cape Cod, in common with many other sections of the country, suffered this year from a rather severe visitation of the army worm (*Heliophila unipuncta* Haworth). It did quite a little damage on bogs here and there, but the cases of great injury appear to have been few. The cranberry is evidently not a favorite food plant with this insect. It usually works on grasses, grains and corn. As it prefers low lying land, however, the moths frequently, in "army worm years." deposit their eggs in quantities on the bogs, and then the vines are attacked because of the absence or scarcity of grasses. Rarely, however, is a large bog seriously hurt on more than a few sections. The growers probably need not fear this insect in 1915, for it rarely appears in great numbers two years in succession, as its natural enemies soon control it.

The gypsy moth (*Porthetria dispar* L.) is becoming more of a menace every year. Numerous reports of threatening danger from it were received during the season of 1913, and this year it has caused no little damage on bogs in several localities. It is becoming more abundant yearly on the uplands around the bogs in much of the cranberry section. The danger to the bogs themselves, except possibly where water for reflowage is abundant, evidently grows greater in proportion to this upland increase, for while the female moths cannot fly onto the bogs to lay eggs the small worms can readily be blown on by the winds. This insect, therefore, is fast becoming a cranberry problem, and it must be given more attention from now on. The following matters in connection with it need to be determined especially: —

1. In the more serious cases of bog infestation, does the trouble arise from eggs laid on the bog the year before or from small caterpillars blown on by the winds early in the season?

2. Can gypsy moth eggs survive winter flooding, if the water is held until late in May? It is known that they can endure an ordinary winter flowage (until April 1). In case severe bog infestations usually arise from eggs deposited the previous season, knowledge concerning the limit of their ability to endure submergence becomes of prime importance.

3. What is the best time to reflow to destroy this insect? The caterpillars are very hairy and will float for a long time before they die. The larger they are the longer they can probably live in this way. For this reason a bog should probably be flooded as soon after the eggs hatch, or after the worms are found at work, as possible. The insect net which has been recommended for discovering the first stages of the false army worm probably would be useful in detecting the presence of the small gypsy moth caterpillars early in May. When a bog infested with this insect is flooded, the worms usually float ashore alive in large numbers, and must be killed by burning or by spraying with crude oil or kerosene.

The cranberry weevil (*Anthonomus suturalis* Lec.), which occasionally harms a bog by working within the blossom buds and eating out their hearts, thereby preventing blooming and fruiting, did much damage on some bogs in Plymouth in 1913, and also caused some loss in the same locality this year. Heretofore no effective treatment has been known for this insect. Attempts to destroy it by flooding have been uniformly unsuccessful. The results of some spraying done this year under the supervision of Mr. Henry J. Thayer of Boston, in anticipation of injury from this insect, are therefore interesting. Arsenicals ("Bordo Lead" with Paris green) were used while the vines were in bud, some time before any blossoms had opened. The bogs thus sprayed and adjacent unsprayed vines were examined in August. The weevil evidently had done much less damage where the spray had been applied.

The spanworm (*Epelis truncataria* var. *faxonii* Minot), discussed in last year's report (pages 50 and 51), was found to have seriously damaged a bog in Wareham. Growers of large and long experience in the vicinity, when shown these worms, expressed the opinion that this species was the one which used to be so commonly and widely injurious on the Cape bogs. If they were correct in this, as seems most probable, the name "Cranberry Spanworm," given by Dr. J. B. Smith to *Cleora pampinaria* Gn., is more deserved by this species. Caterpillars of this insect were collected on the infested Wareham bog on July 23, 1913. By August 8 many of these worms had pupated, and many pupæ of an Ichneumonid parasite were also found, from 25 to 30 per cent. of the worms apparently having been infested with it. The adult parasites emerged from their pupa cases on dates ranging from June 12 to June 27, 1914. They proved to be a dark-colored species of *Campoplex*, with a broad reddish band about the abdomen. This parasite is new to science, and its full description will soon be published by the writer elsewhere.[1]

The infested Wareham bog was visited again on May 28, 1914, and live pupæ of the spanworm were found under the vines in large numbers. The bog had been winter flowed in December, and the water had been let off on May 10, the pupæ thus having survived a five months' submergence. This confirms the observations in connection with this insect on the Yarmouth bog, where the entirely naked (that is, without any cocoon) pupæ endured flooding for more than four months with but a small percentage of mortality. No moths of this insect were observed on the Wareham bog on May 28.

The "tip worm," the "flowed-bog fireworm" ("black head cranberry worm") and the "fruit worm" are of such importance and so constantly troublesome that our investigations with them deserve special and detailed consideration.

The Cranberry Tip Worm (*Cecidomyia oxycoccana* Johnson).

In 1911, a serious dying of the tips took place on the station bog soon after the vines went out of bloom. Evidently largely as a result of this, the bog did not bud up well for the following season, and the small crop of 1912 (less than 200 barrels) was the result. Until this year the writer thought this tip trouble was secondary to some injury to the root system, caused, perhaps, by mismanagement in the use of water during the growing season. This idea seemed to be substantiated by the fact that dry bogs (without winter flowage) near the station bog showed but little of the tip injury in 1911. The station bog was resanded in the fall of 1911, and the winter flowage was held late (until the 17th of May) the following spring. In 1912, little of the injury occurred on the bog, the bud formation for the following season being almost perfect and resulting in the splendid crop obtained in 1913. In 1913, the injury was again considerable, though the bud development was fairly good, and the 1914 crop following those conditions was a fair one. This year the tips died badly, and the budding for 1915 was poor.

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[1] Entomological News, XXVI, 1915. (*Campoplex variabilis* n. sp.).

The tips have been carefully examined every year since this trouble was first noticed, but the cause of the injury was not discovered with certainty until 1914. The tip worm was suspected from the first, but as the maggots of the broods which appear before blooming time were known to always make their cocoons in the tips of the vines, the cocoons remaining as certain evidence of their work even after the flies themselves had emerged and disappeared, it was thought that at least cocoons, if not maggots, ought to be found in connection with the tip injury coming after the bloom, if it was caused by this insect.

This year a special effort was made to ascertain the cause of the trouble. The tips were examined before they showed injury, while the bog was in full bloom, and maggots in various stages of development were soon found in a good share of them, as many as five sometimes being present in one tip. Tip worm eggs were also found in abundance. In less than three weeks the infested tips had dried up, the maggots having disappeared without leaving cocoons. There was no longer any doubt as to the cause of the injury observed in previous seasons. It was soon found that the maggots of this, the most injurious brood, leave the tips and go down to the sand under the vines to form their cocoons. Unfortunately, it was not discovered in what condition the insect passes the winter. It is suspected that it may remain in the cocoon and be able to endure winter flooding.

As soon as this insect was found in such abundance on the station bog an examination of other bogs was begun, and a great variation was found among them in the amount of tip worm damage, due, apparently, to the treatment they had received. Two-thirds of the tips on the station bog were injured, and practically all of them were hurt on a bog of 4 or 5 acres in Carver. On some bogs, however, the damage was only from 3 to 5 per cent. From 50 to 60 bogs were examined in the course of this investigation, and it resulted in the following conclusions: —

1. That flowed bogs, in case they had not been resanded before the 1st of May, were, as a rule, much more seriously injured than were strictly dry bogs (without winter flowage). In its relative abundance on dry and flowed bogs, the tip worm seems to be in a condition similar to that of the flowed-bog fireworm, though the reasons for the condition may not be the same with both species.

2. That flowed bogs which had been resanded the fall before or in the spring before the 1st of May were, as a rule, much less seriously injured than those not thus resanded. In nearly every case those most hurt had not been resanded for two years or more.

3. The "Late Howe" variety, as a rule, showed distinctly more injury than did the "Early Black."

4. No bog showed great tip worm injury where traces of severe frost damage were in evidence.

5. This seems to have been a year of exceptional tip worm abundance. It is not yet certain why resanding, winter flooding, difference in variety and frost have bearings on the prevalence of this insect. It seems evident, however, that resanding every other year should be recommended as a wise preventive practice against it.

The injury caused by this brood which does its work during the time of full bloom is a matter of great importance. It has undoubtedly been the cause of many a crop failure supposed to have been due to other troubles. Early in October, the tips on the station bog were carefully examined to find out whether there had been much recovery from this injury. It was found that less than half of the injured tips had formed buds for next season. The following count of "Late Howe" tips, made on October 1, showed the most recovery of all the counts made: tips not injured, 39; injured tips which had recovered and formed buds, 31; injured tips which had not formed buds, 34. In many cases the buds on the recovered tips were undersized, and it seemed doubtful if the majority of them were normal. The poor recovery on the station bog may, of course, have been due to a devitalized condition of the vines, but the evidence at hand indicates that this insect is a very serious pest.

The Flowed-bog Fireworm (*Rhopobota vacciniana* (Pack.)).

General observations concerning this insect were made during the year, but no extensive experiments were carried out with it because the tip worm and fruit worm monopolized attention. It seems wise, however, to sum up in this report the possibilities for treating this insect satisfactorily.

1. Where reflowing can be done in June, reasonably effective treatment may be had by using the water according to suggestions and recommendations made in previous reports, and perhaps no improvement in treatment is possible for such bogs.

2. Winter-flowed bogs which cannot be reflowed must either have the flowage held late enough (until, perhaps, June 20) to kill the eggs, as often as an infestation develops sufficiently to do serious damage, the crop being sacrificed in the years of such late holding, or else be sprayed, if any direct treatment is to be applied at all. Arsenical poisons seem to have been pretty thoroughly tested by the growers in practical spraying for this insect. A great advantage is often obtained by their use, but under some conditions the results are very unsatisfactory, and the frequent failures with such treatments have created a general desire for some better method. Only one possibility for great improvement in spraying treatments seems to present itself. Possibly a sweetened spray would be attractive to the worms. Some growers claim to have tried such a spray with exceptionally good results, but it is doubtful if this method of treatment will be found practicable on more extensive trial. Sweetened sprays are nowhere widely used in treating any chewing insect, and if such a treatment were practicable it would probably have come

into extensive use with other insects long ago. Sweetened poison baits have long been widely used against grasshoppers and cutworms, and molasses is commonly used by entomologists to attract many kinds of moths in night collecting. Sweets are, therefore, evidently liked by many insects, and the idea of sweetening arsenical sprays seems worth trying out thoroughly on that account. The fireworm's hatching period, however, often covers several weeks, and, in order to be satisfactorily effective, any poison application must remain on the vines in considerable strength for quite a long time. Sweets being very soluble in water, if used in a spray, will not remain on the vines long if much rain falls. There are, therefore, considerable difficulties to be overcome in making satisfactory use of a sweetened spray.

The outlook, therefore, does not seem bright for treating this insect more satisfactorily by direct methods. It may be possible, however, to treat it indirectly in some way. As stated in previous reports, it does not seriously infest bogs without winter flowage. If infested bogs could be left entirely without flowage, the insect would in time probably be controlled by weather conditions and its natural enemies. If bogs are not winter flowed, however, other troubles have to be met. In the first place, there is the danger of winterkilling, though this factor is not as important as is generally supposed, for severe winter injury does not occur on dry bogs oftener than once in four or five years, and even then the bogs are seldom so hurt that they do not produce partial crops and recover in fair shape for the following year. The fruit worm increase which takes place when winter flowage is omitted is, however, a serious matter, and a satisfactory treatment for that insect is, for that reason, a possible key to the fireworm situation. If the fruit worm could be controlled without winter flooding, the forces of nature could be brought to bear in the fight with the fireworm by omitting flowage altogether.

The Cranberry Fruit Worm (*Mineola vaccinii* (Riley)).

Late holding of the winter flowage continues to be the only certainly reliable method of dealing at all satisfactorily with this insect. A better treatment is desired because the water does injury when held late every year. Any new treatment of value must probably be an indirect one.

As stated in last year's report (page 57), tests showed that the cocoons of the fruit worm are not impervious to water, for they were found to be wet inside when carefully opened after only a few minutes' submergence, the water apparently having penetrated them almost instantly. This was further tested later by wetting dry cocoons with a spray from a Vermorel nozzle, and the water seemed to strike through them as readily as it would have through a handkerchief. It seemed from this that it might be possible to kill the worms in their cocoons on the bog by spraying with some contact poison, as the spray would evidently soak through the cocoons at once. The writer conducted laboratory experiments with "Scalecide" and "Black Leaf 40" to determine what strength of each it would take to kill the worms in this way. They were not killed when the cocoons were kept wet with a mixture of 1 part of "Scalecide" in 5 parts of water for a whole hour. As it would take not less than 600 or 700 gallons to wet down the surface of the sand on a bog, especially if the vines were at all thick, it became evident without further tests that "Scalecide" could not be used successfully in this way because of expense. It took a strength of 1 gallon of "Black Leaf 40" in 100 gallons of water to kill the worms when sprayed on the cocoons, and therefore treatment with this insecticide also seems too expensive to be practicable. However, further tests with other contact sprays are planned.

For dry bogs (without winter flowage) the possibilty of starving out this insect by destroying the bloom in seasons of light crop promise is still under consideration. Success in killing the blossom by spraying with a 20 per cent. solution of iron sulfate was reported last year. As it took three sprayings to destroy all the blossoms, however, it appeared that there might be danger in this method of treatment, as the application of so much iron sulfate might injure the vines. To determine this point, the sulfate salt was applied broadcast on two bog plots on June 17, this year, at the rate of 1 ton to the acre. A few of the vines showed a little injury afterward, but as far as the evidence obtained went, the sulfate may be used to kill the bloom without fear of its doing much damage. It is planned to test this matter further, however.

The study of the natural enemies of the fruit worm were continued, and many things of scientific importance were learned about its parasites. Some of this new information may in time lead to valuable practical results. In all, nearly a dozen species parasitic on this pest have been bred, but only three of them are abundant enough to be of much importance. These three species are: —

1. A Braconid (*Phanerotoma tibialis* Hald.), discussed in last year's report (pages 55 and 56). Cocoons containing worms parasitized by this species can usually be readily distinguished from those of normal, unparasitized worms by their much smaller size. When this parasite was reported on last year, it was assumed that it laid eggs in the eggs of the fruit worm when it parasitized them. This year's observations, however, seem to indicate that instead of laying eggs it injects living young into the fruit worm eggs, and is therefore viviparous. The writer failed to find the eggs of the parasite, but its larvæ can readily be found in fruit worm eggs even before the worms themselves have taken distinct form.

2. An Ichneumonid (*Pristomeridia agilis* (Cress.) Ashm., determined by R. A. Cushman of the United States national museum). This species was also mentioned in last year's report (page 56), but more knowledge concerning it has been obtained this year. It inserts its elongate, curved, black eggs into the body of the fruit worm, usually accomplishing this by sticking its egg-laying apparatus into the hole made in the berry by the worm. The eggs hatch within a few days after they are deposited in the tissues of the worm. This is a far less important parasite than the Braconid

(*Phanerotoma*), not only because it is much less abundant, but also because it usually deposits its eggs in worms which have already been parasitized by the Braconid. It is perhaps as much of a hindrance as a help because of this interference with the Braconid.

3. A Chalcidid (*Trichogramma minuta* Riley,[1] which is known to be parasitic on the eggs of forty-six other species of insects, the codling moth, the brown-tail moth, the pear-slug, the elm saw fly (American Cimbex), the fall web-worm, the corn ear-worm and the cotton worm being some of its important hosts). This, the most important parasite of the fruit worm, was a new find this year. It undergoes all its development and transformation in the fruit worm egg, causing the destruction of the egg, as far as the development of the worm is concerned, and emerging from it in July and August as a full-grown fly-like creature of such small size as to be hardly visible to the naked eye. Its presence in the eggs may be readily detected by their appearance, for they turn black when infested with it. Moreover, when the fruit worm itself hatches, the eggshell is left looking like a white flake, and the worm's place of emergence is not readily seen because of its location close to the surface of the berry. On the other hand, when the parasite has emerged the eggshell looks black and the emergence hole is conspicuous. The writer has noticed these black eggs several seasons, and, as he suspected parasitism in connection with them, he attempted to rear the parasites last year, but failed to do so, probably because the methods he employed were not suited to these very delicate creatures. This year, however, different methods were tried, and the adult parasites were obtained in considerable numbers without much trouble. This parasite destroyed about 56 per cent. of the fruit worm eggs on dry bogs near the station bog this year, about 700 eggs having been examined in making this estimate.

In last year's report (page 55), it was estimated that more than 50 per cent. of the fruit worms on a dry bog near the station bog had been parasitized in 1912. As nothing definite was then known about the Chalcidid egg parasite and its importance, that estimate was much too low, this year's investigations having shown that the natural enemies (parasitic and predacious) of the fruit worm took care of not less than 90 per cent. of the infestation on dry bogs, and of fully 66 per cent. on flowed ones, in the vicinity of the station during the season.

The writer's findings concerning the natural enemies of the flowed-bog fireworm and the bearing which flooding has on their effective activity have been discussed fully in previous reports, but they must be briefly brought to mind again here to show how they are supported by the results of this year's study of the distribution of the principal fruit worm parasites. The fireworm seriously damages only flowed bogs, and it becomes a pest because the flowage either drives out or destroys its natural enemies, but does the insect itself no similar harm. A fireworm infestation always becomes noticeably injurious first at some distance from the upland, and bogs of large size and compact form are much more often badly infested than are smaller ones. This is due to the fact that it takes some time for the natural enemies of the pest to work in from the upland and become effectively numerous on all parts of a large bog, especially on the middle part, after the spring flooding is done. In connection with this fireworm situation, the following findings, concerning this year's distribution of fruit worm parasites on the station bog and on a dry bog near by, are distinctly interesting, the figures given in the table showing the percentage of fruit worm eggs or worms found parasitized in the different locations indicated: —

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[1] Since this was written, this determination has been confirmed by Mr. A. A. Girault, the authority on the *Trichogrammatidæ*.

TABLE 6. — *Distribution of Effectiveness of Principal Fruit Worm Parasites.*

PARASITE.	Eggs or Worms of Fruit Worm examined.	Dry Bog.	Center of Station Bog.	Edge of Station Bog. (1)	Edge of Station Bog. (2)	Edge of Station Bog. (3)
Chalcidid, . .	Eggs, . .	56.0	14.0	28.0	44	–
Ichneumonid, . .	Worms, . .	26.4	4.6	10.4	10	10.6
Braconid, . . .	Worms, . .	47[1]	43[1]	–	–	–

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[1] Because of a mathematical error by the writer, the percentages (32 and 30) given in the Report of the 27th Annual Meeting of the Cape Cod Cranberry Growers' Association, 1914, page 21, were incorrect.

It will be seen that the distribution of the Chalcidid and Ichneumonid parasitism was, in a general way, like that found to obtain, as shown in previous reports, with the enemies of the fireworm. The dry bog used in this comparison is about two acres in area. The center of the station bog is about 250 feet from the upland. The three "edge of station bog" locations were on different sides of the bog. The examinations on which these figures are based were made during the first two weeks in August. Each figure is an average, representing numerous examinations. The station bog was reflowed for the last time a little over seven weeks before these parasite investigations were made. When all these facts are considered, the great influence of flooding on the distribution of the first two of these parasites becomes at once apparent. It will be seen, however, that the water did not seem to affect the Braconid very much, the results of the investigation in this regard being contrary to those of last year's rearing tests. If last year's report is referred to (page 56), however, the following remark concerning the results of those tests will be found: "From a study of the life history of *Phanerotoma tibialis*, it is not easy to see just how the flowage can affect its prevalence to so marked an extent." In the present opinion of the writer it will be found that flooding does affect the abundance of *Phanerotoma* considerably, though probably not to the extent indicated by the results of the 1913 investigations.

In studying the fruit worm parasitism, the writer has had the two following practical objects in view: —

1. *The Possibility of forecasting Seasons of Great Fruit Worm Injury.* — If relative abundance and scarcity of the parasites in different years has a strong bearing on the comparative abundance of the pest, we should probably be able to foretell with some degree of accuracy, after keeping records of the parasitism for several years, what is to be expected in this regard several months ahead.

2. *The Possibility of increasing the Natural Effectiveness of the Parasites by harboring them artificially in Some Way.* — Not enough has yet been learned about the Chalcidid parasite to make any definite plans in relation to it in this connection. The Braconid (*Phanerotoma*), however, can probably be handled without much difficulty, and experiments are already under way to determine whether its percentage of mortality is much greater under natural out-of-door "dry bog" conditions than it would be if its host worms were kept under the more even conditions of temperature and moisture which they would have in cold storage or in ordinary cellars. It is evident, of course, that on flowed bogs the majority of these Braconid parasites perish during the winter, and if the water is held late (until the latter part of May) they are probably almost exterminated. If, therefore, they can be wintered under artificial conditions without much loss, it ought to be possible to replenish the *Phanerotoma* parasitism on flowed bogs by gathering fruit worms every summer, allowing them to form their cocoons in captivity, wintering them in cold storage and returning the parasites to the bog when they emerge the following season. Of course many unparasitized worms would be wintered in this process, and as a result many moths would emerge with the parasites, but there is so much difference in size between the moths and parasites that they could be readily separated with a screen. After they were separated the moths, of course, would be destroyed.

Further submergence tests with fruit worms in their cocoons were begun on September 7, 15 different lots of a dozen each being submerged in water in long glass tubes 2 inches in diameter, at depths varying from 4 to 67 inches, on that date. All the worms used in these tests were collected from a bog, in their berries, between the 12th and 21st of August. They were submerged seventeen days, being removed from the water on September 24, and were all found to have been killed by the treatment. The tubes were kept in the station screen-house during these tests, and the water may have killed the worms because of its abnormal stagnation and high day temperature.

On October 19, further submergence tests were started, a part of the cocoons being put in water in tubes in the screen-house as before, while a part were submerged in light netting sacks suspended from a float in a pond. Some of these cocoons were removed from the water on November 4, after sixteen days of submergence, while others were kept submerged for twenty-five days, until November 13. On both dates it was found that all the worms which had been in the glass tubes were dead, while most of those taken from the pond were alive and capable of crawling actively soon after they were taken from their cocoons. The results of this test led to the suspicion that the worms in the tubes had died because of the extreme stagnation of the water, while those in the pond had perhaps been kept alive by air thrashed into the water by the wind.

A third lot of tests was started on November 12, two of the long glass tubes used in the previous tests being submerged in an upright position in a pond, netting sacks containing fruit worms in their cocoons being tied inside the tubes and also outside of them at different depths ranging from 9 to 61 inches. One tube was taken from the water on December 15 and the other on December 22. Of the 23 worms submerged with the former tube, the 6 outside ones were all lively, while 8 of the 17 inside were dead. Of the 21 worms submerged until the 22d, the 5 outside were all very much alive, while 3 of the 16 inside were dead. The tubes got dragged badly by the ice just before the first one was taken from the water, and most of the cocoon-containing sacks attached to the outside were torn from both, one being left with each. On the whole, the worms endured this prolonged submergence remarkably well. The stagnation of the water inside the tubes seemed to harm them somewhat.

From these and other submergence tests, it was learned that the fruit worm in its cocoon has great ability to resist drowning aside from any protection provided by the cocoon. The cocoons completely filled with water in about five days, so that the worms within them were entirely surrounded by it, there being no air bubble left to help keep them alive.

Water Movement in Peat.

As a part of the general study of cranberry bog drainage and irrigation, it seemed desirable to learn something about the rate of the passage of water through peat, as compared with its movement in other soils. For this purpose, on May 25, 12 holes 3 feet deep were dug 8 feet apart in the station bog, in a line running straight across a section 96 feet wide, those at each end of the line being located 4 feet from the ditch. Stakes were driven in these holes, and levels from which to measure the rise and fall of the water in each were carefully determined and marked upon them. In the latter part of May and in June and July observations and records were made, in connection with the vertical movement of the water in these holes, whenever the bog was being flooded or drained.

The record of May 29 is given here in full, it being fairly representative. In the morning, the ditches surrounding the section in which the holes were dug were comparatively empty, no standing water being visible in any except the large main ditch. The water level in one of the two middle holes (hole No. 7) was taken just before the bog pump was started at 9.30 A.M. and was found to be 97.16, as measured from a bench mark the elevation of which was regarded as 100 feet. It was practically the same in hole No. 6. The pump was run for one and one-quarter hours, until 10.45 A.M., when holes Nos. 1 and 2 on one side of the section and Nos. 11 and 12 on the other side were full of water which had run over the surface of the sand into them. The water level in the ditches and these holes was then, as measured from the bench mark, 98.75. The surface water had not run into the other holes at all or come anywhere near them. At noon, one and one-quarter hours after the pumping was done, the water levels in the 12 holes and in the ditches were taken and found to be as follows: —

Ditch,	98.48	Hole No. 7,	98.07
Hole No. 1,	98.53	Hole No. 8,	98.10
Hole No. 2,	98.34	Hole No. 9,	98.17
Hole No. 3,	98.17	Hole No. 10,	98.09
Hole No. 4,	98.15	Hole No. 11,	98.30
Hole No. 5,	98.09	Hole No. 12,	98.37
Hole No. 6,	98.00		

This record shows a variation of only about 6⅓ inches in the water level two and one-half hours after the pumping was begun. Similar measurements were made again at 3.30 P.M., six hours after beginning pumping and four and three-quarters hours after stopping, and the variation was then found to be only about 1⅔ inches, the various levels being as follows: —

Ditch,	98.29	Hole No. 7,	98.21
Hole No. 1,	98.29	Hole No. 8,	98.21
Hole No. 2,	98.26	Hole No. 9,	98.26
Hole No. 3,	98.20	Hole No. 10,	98.21
Hole No. 4,	98.20	Hole No. 11,	98.26
Hole No. 5,	98.17	Hole No. 12,	98.26
Hole No. 6,	98.15		

The pump was started again at 4.20 P.M. (May 29) and run until 7 P.M. The planks were then put in, and all the water was held until 2 A.M. the following morning, at which time the water level on the bog was 99, all the 12 holes used in making the above measurements being entirely full. The water was allowed to run out of the bog freely from 2 A.M. until 10.45 A.M., when the levels in the ditches and in the holes were again taken and found to be as follows: —

Ditches,	97.48	Hole No. 7,	97.78
Hole No. 1,	97.57	Hole No. 8,	97.71
Hole No. 2,	97.71	Hole No. 9,	97.72
Hole No. 3,	97.71	Hole No. 10,	97.76
Hole No. 4,	97.73	Hole No. 11,	97.66
Hole No. 5,	97.71	Hole No. 12,	97.63
Hole No. 6,	97.79		

The elevation of the surface of the peat around these holes averaged roughly about 98.59. There was, therefore, a drainage in the peat of considerably over 9 inches in less than nine hours, at the middle of the section, at a distance of 44 feet from the nearest ditch. This shows that the horizontal movement of water through the peat of cranberry bogs is a very rapid one, if conditions at the station bog are representative.

Root Development.

A study of the seasonal development of the root growth of the cranberry was begun in a rough way and produced some interesting results. As stated in last year's report, Professor Coville, of the Bureau of Plant Industry of the United States Department of Agriculture, has found that the root development of blueberries, rather closely related to the cranberry, is very sluggish. This is also found to be true of the cranberry, though apparently not to so great an extent. On the fungous plots of the station bog this year there was practically no new root development until after the vines had bloomed, and most of the new growth came after blossoming time on the bog as a whole. The new roots were found, however, to start fairly early on bogs which are not winter flowed, some new growth being discovered on well-sanded portions of such bogs as early as May 7.

The winter flowage was let off from the station bog on May 5, and no new roots could be found on it on May 7. On May 26, a considerable growth of new rootlets had already taken place near the surface, but the lower roots showed no new development whatever. A season's root growth on cranberry bogs evidently begins, therefore, at the surface of the sand, where the roots have the most air and heat. In examinations made later in the season new roots were finally found deeper down in the bog, but the conditions that favored the starting of development near the surface evidently continued to have their influence more or less throughout the period of growth, causing the greater part of the season's root growth to be developed within two or three inches of the surface.

The degree of drainage does not seem to affect the new root development in the first part of the season (before the 1st of June), except that when the water table is so high (within three or four inches of the surface) that it makes the surface sand soppy the new rootlets are distinctly larger and more succulent than when they grow under dryer conditions.

Studies of the *Mycorhiza* fungi on cranberry roots were begun in a rough way, with the idea of first finding out, if possible, whether there is any great difference in the abundance of these fungi present in different sorts of bogs, attention being given particularly to comparisons between flowed and dry bogs, old bogs and new plantings, and vines growing on "hard bottom" and on "peat bottom." While this investigation has not advanced far enough to justify definite conclusions, it is apparent that different bog conditions have a considerable bearing on the abundance of these fungi.

MISCELLANEOUS.

After most of the cranberry crop had been gathered, the fallen berries were picked up from under the vines on a large number of measured plots on the station bog and other bogs in the vicinity, to determine how much of the fruit was lost in different methods of harvesting. The loss ranged from an average of about 10 per cent. where the scoops were handled slowly and carefully to an extreme loss of over 25 per cent. where bogs with heavy crops were scooped hurriedly. The general conclusion arrived at from this investigation was that with low prices such as obtained this year, especially with the early berries, it is advisable to scoop rapidly on bogs with light or medium crops. Under the normal price conditions of previous years, however, it would pay, with heavy or medium crops, to pick slowly and carefully, prevention of waste being much more important than the keeping down of the labor expense of picking. It would sometimes pay, under such conditions, to spend as much as 80 cents a barrel on "Early Blacks" and $1 a barrel on "Late Howes" for careful scooping. Most of the berries dropped in scooping seem to be knocked off by the tips of the teeth of the scoop. For this reason, a scoop with teeth having rounded and flattened ends would probably lose less berries than one with pointed teeth.

This year of low prices has been generally discouraging to the cranberry growers. It will undoubtedly, however, benefit those interested in the industry to some extent by tending to curtail the planting of new bogs in the immediate future. Such prices may not prevail again for many years, for, as is generally realized, this year's conditions were very exceptional in many ways. If the time ever comes when very low prices are the rule year after year, the situation will not be hopeless, for, as in every other business, changes in methods will necessarily accompany changes in conditions. With low prices the rule, no attempt probably would be made by most growers to combat the various pests by methods now employed. The fruit worm, flowed-bog fireworm, tip worm and various other insects which occasionally become troublesome would be entirely controlled by holding the winter flowage very late (perhaps until nearly the 1st of July) every other year (or possibly every third year). Though the crop would be entirely lost in the year of late holding, its loss would be largely offset by the almost entire elimination of expense, and the crop of the following year, being free from the most commonly troublesome pests, and having behind it the strength of vines not weakened by the drain of a crop the year before, would give the best returns possible. The average quantity of berries produced yearly would perhaps not be as great as that obtained by present methods, but even with low prices the profits might not be seriously diminished, since a considerable reduction in expenses would be brought about by such management.

Cranberry growers frequently desire to know how high a temperature the water of June reflowage can have without doing serious damage to the buds. The experience at the station bog in the last two seasons, therefore, should be both interesting and reassuring. Very hot weather occurred both years during the regular June reflow. The temperature of the water on the bog was taken with a Green thermometer, and the maximum reading obtained each year was 86° Fahr. In 1914, the reflow was continued for two days, the temperature of the water being 86° Fahr., at noon the first day and 81° the second. The withdrawal of the flowage was started at 2 A.M., the temperature of the water at that time being 71°. Higher temperatures probably will seldom be experienced in flooding. There was practically no damage to the buds.

BLUEBERRIES.

Owners of many "dry bogs" on the Cape will be interested to know of the work which has been done with blueberries in the New Jersey cranberry growing region. Prof. Frederick V. Coville of the United States Department of Agriculture and Miss Elizabeth C. White of New Lisbon, N. J., have co-operated in the selection and breeding of blueberries and have produced varieties with fruit of such superior size that the commercial growing of this fruit is soon to be taken up extensively by some of the New Jersey cranberry growers. There seems to be no reason why these blueberries should not do as well on Cape Cod as in New Jersey, and the peat soils used for growing cranberries are entirely suitable for them. Many dry bogs which are at present poor investments could, without doubt, be converted into blueberry plantations with great profit.

BULLETIN No. 161 APRIL, 1915

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

The Effect on a Crop of Clover of Liming the Soil

By F. W. MORSE

AND

Toxic Effect of Iron and Aluminum Salts on Clover Seedlings

By R. W. RUPRECHT

This bulletin shows that liming a soil increases the size of clover plants and the percentage of nitrogen in them when the clover was grown on soils without an application of nitrogen or when supplied with sulfate of ammonia. The increase in the assimilation of nitrogen was apparently promoted by the action of the lime on the properties of the soil and not by its action within the plants.

Sulfate of iron and sulfate of aluminum are shown to be very harmful to the roots of clover plants. Carbonate and hydrate of lime neutralize the injurious properties of the salts of iron and aluminum in dilute solutions.

Requests for bulletins should be addressed to the
Agricultural Experiment Station,
Amherst, Mass.

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[1] On leave.

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Approved by
The State Board of Publication.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY.

J. B. Lindsey, *Chemist in Charge.*

THE EFFECT ON A CROP OF CLOVER OF LIMING THE SOIL.

BY F. W. MORSE.

This study of the effect of liming a soil on the composition of a crop of red clover has been made in the course of investigating soil-fertility problems connected with the oldest series of fertilizer plots at the Massachusetts Agricultural Experiment Station. The plots have been repeatedly described in the annual reports of the station, under experiments with nitrogenous fertilizers, and designated as "field A."

A brief description of the plots at this point will serve to make this particular study intelligible. The soil is a sandy loam, and the plots referred to in this paper have received only chemical fertilizers for a period of thirty-one years. No dung or litter has been applied, and organic matter has been supplied wholly by crops grown on the land in the form of roots and stubble, with an occasional catch crop plowed under.

Since 1890 the annual application of chemicals has been 45 pounds of nitrogen per acre in nitrate of soda or sulfate of ammonia; 80 pounds of phosphoric acid per acre in dissolved bone black, and 125 pounds of potash per acre in muriate of potash or the double sulfate of potash and magnesia.

Table I. shows the distribution of the different fertilizers among the plots.

Table I.

Plot 1. Nitrate of soda, dissolved bone black, muriate of potash.
Plot 2. Nitrate of soda, dissolved bone black, sulfates of potash-magnesia.
Plot 4. No nitrogen, dissolved bone black, sulfates of potash-magnesia.
Plot 5. Sulfate of ammonia, dissolved bone black, sulfates of potash-magnesia.
Plot 6. Sulfate of ammonia, dissolved bone black, muriate of potash.
Plot 7. No nitrogen, dissolved bone black, muriate of potash.
Plot 8. Sulfate of ammonia, dissolved bone black, muriate of potash.

The more recent history of cropping is as follows: in August, 1906, alsike clover was sown in the standing corn then occupying the field. The land remained unplowed for three years. The stand of clover was poor, and each spring additional seed was sown on the surface, but grasses crowded into the bare spaces. In August, 1909, one-half of the field was limed at the rate of 3,000 pounds per acre with slaked lime, the application being made crosswise of the plots, so that every plot was half limed and half unlimed. Alsike clover was again sown, but as in preceding years the crop of 1910 consisted of more grass than clover.

In 1911 and 1912 corn was grown with good yields on all plots, and in the former year the product of the plots receiving no nitrogen, plot 4 and plot 7, was practically equal to that from plots 1 and 2, which received nitrate of soda. Attempts to get a stand of alsike clover were made in both years by sowing the seed in the standing corn late in July. Germination was good, but the clover was badly winterkilled both years.

The liming of one-half of the area in 1909 showed no appreciable results on either corn or clover. Therefore in 1913, when it was apparent that the land must again be plowed, another dressing of hydrated lime was applied at the rate of 4,000 pounds per acre.

Japanese millet was grown in 1913 with fair yields, but the crop was cut short by drought. The growth did not appear to be much influenced by the lime. In the spring of 1914 the plots were seeded with red clover, together with oats as a nurse crop. The oats were removed in July, and there were pronounced effects of the liming observable on all the plots, least on the plots receiving nitrate of soda.

After the oats were removed the clover on the limed halves of plots 4 and 7, receiving no nitrogen, was first to appear above the stubble. The clover on the whole area of plots 1 and 2, receiving nitrate of soda, and on the limed halves of plots 5, 6 and 8, receiving sulfate of ammonia, followed about one week later.

As the season progressed the clover on the limed areas receiving no nitrogen continued to lead all the other plots in size and vigor of growth, and began to bloom several days ahead of them. The whole area receiving nitrate of soda looked uniform to the eye, but a little behind the limed area without any nitrogen. The limed areas receiving sulfate of ammonia were like the areas receiving nitrate of soda. The unlimed areas without nitrogen produced a slow-growing crop which looked scanty in comparison with the growth on the limed portions of the same plots, but an examination of the ground showed the plants to be as numerous on one area as on the other. The clover on the unlimed areas receiving sulfate of ammonia looked noticeably inferior to all other plots without lime, and the division between the limed and unlimed halves of the plots was clearly marked by vigorous, thrifty plants on the limed areas and small stunted ones on the unlimed. A similar line of demarkation existed on the plots receiving no nitrogen, but was barely, if at all, noticeable on the plots receiving nitrate of soda.

The pronounced effect of liming the soil on the growth of clover made it seem possible that a chemical investigation would show some specific effect of the lime on the composition of the plants. Accordingly, samples of clover plants were gathered from both limed and unlimed areas of the plots mentioned in Table I. and samples of clover roots from both halves of plots 2, 5 and 7.

The samples of clover were obtained on Sept. 14 and 15, 1914, when the crops on the limed halves of plots 4 and 7, without nitrogen, were in full bloom, and on the other limed areas were partly so. The unlimed halves of plots 1 and 2, dressed with nitrate of soda, appeared to be as much in bloom as the limed halves, but the remaining unlimed areas showed no flowers nor buds. The samples were gathered by cutting the plants near the ground with grass shears, and each half of a plot was represented by a large number of plants which were taken from all sections of it. The unlimed areas of plots 4, 5, 6, 7 and 8 were most thoroughly represented because the growth on them was so much smaller that many more plants were needed to make samples of sufficient size.

The samples of clover roots were obtained by digging representative plants with a spade, taking up a block of soil about 8 inches in depth. The blocks of soil were exposed to the action of water from a hose-nozzle, care being taken that the rootlets were not broken as the soil was washed away. The process was slow, and it required the time from September 16 to 19, inclusive, to prepare the samples desired. The samples were, however, obtained under uniform conditions, as the weather was fair throughout the sampling. After the roots were washed free of earth they were cut from the plants and dried.

The roots from both halves of plot 2, dressed with nitrate of soda, were large and thrifty and bore numerous nodules. The roots from the limed halves of plots 5 and 7 were apparently similar in all respects to those from plot 2. On the other hand, the roots from the unlimed half of plot 5, dressed with sulfate of ammonia, were much smaller than those from the limed half, and nodules were few and very small. The roots from the unlimed half of plot 7, receiving no nitrogen, were thriftier than those just described, but were not so thrifty in appearance as those on the limed half and bore smaller nodules.

All samples were dried at a temperature around 75° C. until sufficiently brittle to be easily pulverized. They were then ground to a powder, after which moisture was determined in order that all subsequent analytical work could be based on the dry matter. No attempt was made to determine the percentage of dry matter as it was not essential.

The tentative plan for chemical analysis included total nitrogen as the most easily determined organic constituent, total ash as a guide to the mineral constituents, iron oxide and calcium oxide. Iron oxide seemed important because in our soil-fertility investigations Mr. Ruprecht has found soluble iron salts in the unlimed areas of some of the plots,[1] and has studied their effects on the growth of clover.[2] The percentage of calcium oxide in the clover was expected to be modified by the application of lime to the soil, and it was also thought that the iron oxide would be modified somewhat by it. The results of the analytical work are given in Table II.

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[1] Investigations not yet published.

[2] See second part of this bulletin.

TABLE II. — *Composition of Clover (Dry Matter) (Per Cent.).*

		Plot 1.	Plot 2.	Plot 4.	Plot 5.	Plot 6.	Plot 7.	Plot 8.
Ash,	Limed,	11.04	10.79	10.39	10.64	10.35	10.85	10.92
	Unlimed,	10.99	10.31	10.82	10.68	10.51	11.16	11.40
Ferric oxide,	Limed,	.11	.14	.06	.15	.11	.12	.09
	Unlimed,	.13	.13	.09	.20	.09	.16	.12
Calcium oxide,	Limed,	2.04	1.80	1.63	1.85	1.99	1.90	2.01
	Unlimed,	2.21	1.96	1.95	2.05	2.46	2.43	2.51
Nitrogen,	Limed,	3.71	3.60	3.53	3.57	3.66	3.39	3.73
	Unlimed,	3.49	3.28	3.06	2.74	2.64	2.80	2.88

Composition of Clover Roots (Dry Matter) (Per Cent.).

		Plot 2.	Plot 5.	Plot 7.
Ash,	Limed,	7.25	6.79	6.26
	Unlimed,	7.31	7.93	7.12
Ferric oxide,	Limed,	.40	.40	.24
	Unlimed,	.47	.61	.36
Calcium oxide,	Limed,	.59	.53	.60
	Unlimed,	.48	.41	.54
Nitrogen,	Limed,	2.77	2.77	2.45
	Unlimed,	2.43	1.76	1.88

The composition of the samples of clover from the limed areas proved to be more uniform than the composition of samples from the unlimed, the range of percentages between maxima and minima being narrower in the constituents of the former series. The mineral constituents are slightly higher in the clover from the unlimed areas, and this is most positively defined in the percentages of calcium oxide. On the other hand, the nitrogen is markedly lower in the unlimed group of samples.

The composition of the roots differed somewhat from that of the tops. The constituents determined, except iron oxide, were much lower in percentage than those in the tops. The percentages of nitrogen varied in the same manner as in the tops, while calcium oxide was higher in the roots from limed areas, and the iron oxide was higher in those from unlimed areas.

Variations in the percentages of ash in the roots were probably due in part to the presence of clay, which could not be completely washed from the roots. This was clearly indicated by the following experiment. Parallel ash determinations were made on the roots from the unlimed half of plot 5 and those from the limed half of plot 7, which represented, respectively, the maximum and minimum ash percentages. After weighing the total ash it was dissolved in strong hydrochloric acid, then diluted with water and filtered. The insoluble residue on the filter was then ignited and weighed. The soluble ash percentages were nearly alike.

	Plot 5, Unlimed (Per Cent.).	Plot 7, Limed (Per Cent.).
Total ash,	7.45	6.24
Insoluble residue,	2.24	1.20
Soluble ash,	5.21	5.04

The percentages of ash, iron oxide and calcium oxide throw no light on the specific effect of liming the soil. There appears to be neither too much iron nor too little calcium in the tissues of the plants from the unlimed areas, unless the small differences in the percentages from limed and unlimed roots are sufficient to warrant such a deduction.

The marked differences in the nitrogen percentages in the unlimed crops when compared with those in the limed crops justify the deduction that available nitrogen was an important factor in promoting the growth of the plants. It is well known that carbonate of lime is beneficial to bacterial development; therefore it is reasonable to conclude that fixation and nitrification of nitrogen have been accelerated on the limed areas to the marked advantage of the plants, in comparison with those on the unlimed areas.

The increased formation of available nitrogen can be considered as true even for the plots receiving nitrate of soda, because 45 pounds of nitrogen would be completely used in 1,233 pounds of dry matter containing an average of 3.65 per cent. of nitrogen, which is the average for the crops from the limed halves of plots 1 and 2. That amount of dry matter represents a small yield of clover hay per acre, to say nothing of the roots of the crop, which contained 2.77 per cent. of nitrogen. In this instance the clover was not harvested, and we have no weights to confirm our opinion.

Besides the lessened availability of the nitrogen on the unlimed halves of the plots dressed with sulfate of ammonia there was also the probable hindrance to root development due to the presence of sulfate of iron and sulfate of aluminum, noted by Mr. Ruprecht in his work on the soils from these plots. As already noted in the description of samples, the roots obtained from the unlimed half of plot 5 were much smaller than those from the limed half, although they did not show the thickened, dwarfed forms obtained in some of the water cultures.

The results of this work point to an effect of the lime on the soil constituents, by which the root environment is improved, rather than to an effect within the plant by the absorption of a larger amount of calcium salts.

TOXIC EFFECT OF IRON AND ALUMINUM SALTS ON CLOVER SEEDLINGS.

BY R. W. RUPRECHT.

During the study of the soil from field A it was found that marked amounts of soluble aluminum and iron salts were removed from the plots receiving sulfate of ammonia by long-continued washing of the soils with distilled water, while no aluminum and only traces of iron were removed from the plots receiving nitrate of soda. This led to the conclusion that the iron and aluminum salts might be the causes of the poor crops, and water-culture work, using these salts, was undertaken.

At the time these culture experiments were started practically no work of this nature, using iron and aluminum salts in water cultures, had been reported. Since then, however, Connors of Indiana has published[1] results of the toxic action of aluminum on corn seedlings, and Gile has published[2] results of the toxic effect of salts of iron on rice seedlings.

The salts used by me were ferrous sulfate and aluminum ammonium sulfate. The alum was used instead of aluminum sulfate because the latter was not on hand.

Standard solutions of the above salts of one-tenth molecular strength were made up, and different amounts were added to the nutrient solution.

The nutrient solution used was a slight modification of Pfeffers, and was made up as follows: —

Solution (*a*): 20.5 grams $MgSO_4$ dissolved in 350 c.c. distilled water.
Solution (*b*): 40 grams $Ca(NO_3)_2$, 10 grams KNO_3, 20.56 grams Na_2HPO_4 dissolved in 350 c.c. distilled water.

One hundred cubic centimeters of solution (*a*) and 100 cubic centimeters of solution (*b*) were then added to 9.8 liters of distilled water, and a few drops of ferric chloride solution added.

The seeds were germinated on paraffin-coated wire gauze as described in Bulletin No. 70, Bureau of Soils. When the stems of the seedlings reached a length of 1 inch they were transferred to notched corks and placed in the culture solutions.

The culture solutions were contained in salt-mouth bottles of 250 cubic centimeters capacity, with necks having a diameter of 1¼ inches.

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[1] Indiana Experiment Station Bul. No. 170.
[2] Jour. of Agricultural Research, Vol. III., No. 3.

Four seedlings were placed in each bottle. As each experiment was carried on in triplicate this gave a total of twelve seedlings for each treatment.

The first experiment was carried on with aluminum salt and red clover seedlings.

Treatment employed in First Experiment.

1. Nutrient solution (check).
2. Nutrient solution+10 c.c. 1/10 molecular solution of ammonia alum =216 parts per million of Al.
3. Nutrient solution+5 c.c. 1/10 molecular solution of ammonia alum =108 parts per million of Al.
4. Nutrient solution+2 c.c. 1/10 molecular solution of ammonia alum =43 parts per million of Al.
5. Same as No. 2+CaO }
6. Same as No. 3+CaO } approximately .5 gram of CaO was added to each bottle.
7. Same as No. 4+CaO }

At the end of the first week quite marked differences were noticed in the roots, while the tops of all but the check were about alike. The roots of all but the check and No. 7 (43 p. p. m. Al + CaO) were very much stunted. The roots consisted of the single taproot without root hairs. Four days later the tops began showing differences similar to the roots. The worst seedlings were those in the highest concentration of aluminum, the conditions improving with a decrease in the amount of aluminum present. The presence of the calcium oxide seemed to counteract the toxic effect in a marked degree but not entirely, except in the most dilute solution. At the end of four weeks, when the experiment was discontinued, the differences were the same as noted at the end of the first week, only more pronounced. The seedlings in the bottles containing 216 parts per million (No. 2) and 108 parts per million (No. 3) of the aluminum, respectively, had died at the end of the third week, even in those treated with calcium oxide. The check was in excellent condition and No. 7 (43 p. p. m. + CaO) was fair.

In the second experiment a series of cultures with ferrous sulfate was added, and instead of using calcium oxide to neutralize the toxic action of the aluminum salt the carbonate and sulfate were used in order to avoid the danger of having the nutrient solution become alkaline from the calcium oxide. Enough of the carbonate and sulfate was added to make a saturated solution.

Treatment employed in Second Experiment.

1. Nutrient solution }
2. Nutrient solution+$CaCO_3$ } checks.
3. Nutrient solution+$CaSO_4$ }
4. Nutrient solution+2 c.c. 1/10 molecular aluminum sol. =43 p.p.m. of Al.
5. Nutrient solution+2 c.c. 1/10 molecular Al sol.+$CaCO_3$.
6. Nutrient solution+2 c.c. 1/10 molecular Al sol.+$CaSO_4$.
7. Nutrient solution+1 c.c. 1/10 molecular Al sol. =21.6 p.p.m. of Al.
8. Nutrient solution+1 c.c. 1/10 molecular Al sol.+$CaCO_3$.

9. Nutrient solution+1 c.c. 1/10 molecular Al sol.+$CaSO_4$.
10. Nutrient solution+10 c.c. 1/10 molecular sol. $FeSO_4$=22 p.p.m. of Fe.
11. Nutrient solution+10 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
12. Nutrient solution+10 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
13. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol. =11 p.p.m. of Fe.
14. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
15. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
16. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol. =4.5 p.p.m. of Fe.
17. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
18. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.

At the end of three days most of the plants in the higher concentrations of the ferrous sulfate had died. These were replaced, but by the end of the first week these too had died. This failure of the plants to make a start was, I think, in part due to unfavorable weather, there being practically no sunshine during this first week. The same differences as indicated in the first experiment were noticed in this series. Calcium carbonate counteracted the toxic influence of the aluminum salt in both concentrations to a marked degree, but not entirely. In the iron-treated solutions the calcium carbonate had a slightly beneficial effect on No. 14 (11 p. p. m. of Fe), more beneficial on No. 17 (4.5 p. p. m. of Fe), but no effect on the highest concentration (22 p. p. m. of Fe). Calcium sulfate had no effect, the plants being similar to those in the solutions of the same concentrations without the calcium salt. It was also noticed that the seedlings in the solutions containing the iron and aluminum salts without the addition of calcium had a tendency to have stems of a reddish color. The experiment was discontinued at the end of the third week, as most of the plants had died from excessive heat. An extremely hot spell made it impossible to keep the greenhouse cool.

The third experiment was a repetition of the second, with the exception that the highest concentration of the ferrous salt was omitted, and a more dilute one added.

Treatment employed in Third Experiment.

1. Nutrient solution
2. Nutrient solution+$CaCO_3$ } checks.
3. Nutrient solution+$CaSO_4$
4. Nutrient solution+2 c.c. 1/10 molecular aluminum sol. =43 p.p.m. of Al.
5. Nutrient solution+2 c.c. 1/10 molecular aluminum sol.+$CaCO_3$.
6. Nutrient solution+2 c.c. 1/10 molecular aluminum sol.+$CaSO_4$.
7. Nutrient solution+1 c.c. 1/10 molecular aluminum sol. =21.6 p.p.m. of Al.
8. Nutrient solution+1 c.c. 1/10 molecular aluminum sol.+$CaCO_3$.
9. Nutrient solution+1 c.c. 1/10 molecular aluminum sol.+$CaSO_4$
10. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol. =11 p.p.m. of Fe.
11. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
12. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
13. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol. =4.4. p.p.m. of Fe.
14. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
15. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
16. Nutrient solution+1 c.c. 1/10 molecular $FeSO_4$ sol. =2.2. p.p.m. of Fe.
17. Nutrient solution+1 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
18. Nutrient solution+1 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.

As in the previous experiments the roots showed marked differences at the end of the fourth day, while the tops showed no differences until a week had elapsed. The roots of the aluminum and iron treated bottles were very much stunted, and either consisted of only one main taproot without laterals or root hairs, or else quite a number of short thick roots growing from the base of the stem. The laterals only grew about a sixteenth of an inch and then stopped. All of the stunted roots were thicker than the unaffected ones, and despite their much smaller number and shorter length weighed as much as the healthy roots. At the end of six weeks the experiment was discontinued and photographed (Plates I. and II.). The seedlings in the 2.2 parts per million iron solution (No. 16) were almost normal, and where calcium carbonate had been added (No. 17) showed practically no differences from the check. The seedlings in the 4.4 parts per million iron solution (No. 13) made little growth after the first week, but did not die, and where calcium carbonate was added the toxic action was in part overcome. In the 11 parts per million iron solution (No. 10) the plants died at the end of the fourth week. Calcium carbonate in this case seemingly had no effect. As was already noted in the second experiment calcium sulfate had no effect in counteracting the toxic action of the salts. The results with the aluminum salt were exactly similar to those of the first and second experiment.

Summarizing the results of the three experiments we find as follows: —

1. That aluminum sulfate, when present in culture solutions in concentrations greater than 40 parts per million of aluminum, has a very toxic action on clover seedlings.

2. That ferrous sulfate when present in culture solutions in concentrations above 4 parts per million of iron exerts a toxic effect on clover seedlings.

3. That this toxic effect of iron and aluminum can, in a large measure, be overcome by the use of calcium carbonate up to a certain point, beyond which it has no effect. Calcium sulfate does not have this beneficial effect. This would seem to indicate that it was not the presence of calcium alone to which the antitoxic action was due, but rather to the combination in which it is present. Calcium in the form of the carbonate precipitates the iron and aluminum in the form of hydroxides, and thus removes them from solution and counteracts their harmful action. The toxic action of the higher concentrations of iron and aluminum, despite the excess of calcium carbonate present, is due, I think, to the solubility of the iron hydroxide. The aluminum hydroxide being less soluble, the toxic effect, even in the most concentrated solutions, is almost entirely counteracted by the calcium carbonate.

4. The idea that the toxicity of iron and aluminum salts is due to the penetration of the salts into the seedlings does not seem to be borne out. That the toxic action seems to be entirely in the first layer or two of cells in the growing portion of the roots is borne out by the following: a microscopical examination[1] shows that the stunting of the roots is due

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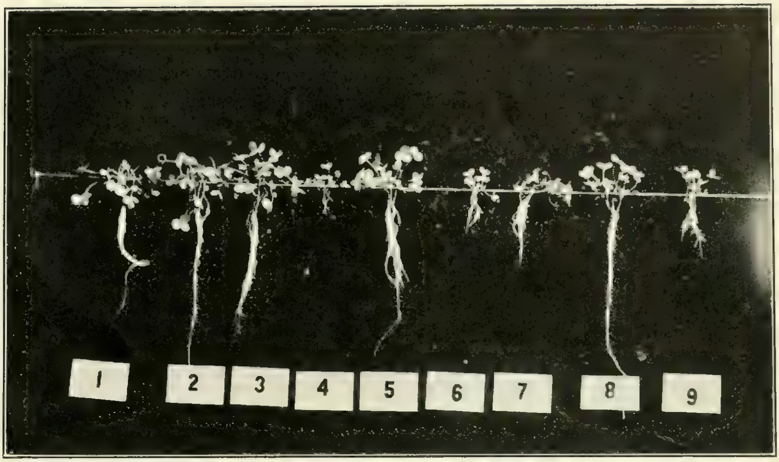
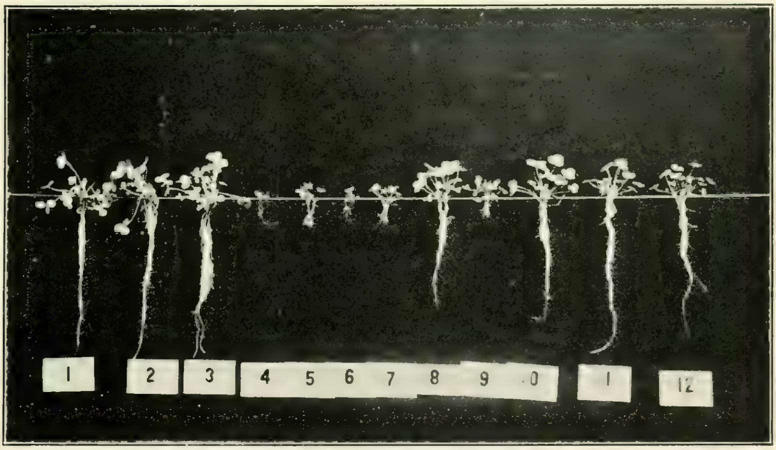
[1] Made by Mr. G. H. Chapman.

PLATE I.



No. 1, Nutrient sol.; No. 2, Nutrient sol.+$CaCO_3$; No. 3, Nutrient sol.+$CaSO_4$; No. 4, Nutrient sol.+2 c.c. Al sol.; No. 5, same as No. 4+$CaCO_3$; No. 6, same as No. 4+$CaSO_4$; No. 7, Nutrient sol.+1 c.c. Al sol.; No. 8, same as No. 7+$CaCO_3$; No. 9, same as No. 7+$CaSO_4$.

PLATE II.



No. 1, Nutrient sol.; No. 2, Nutrient sol.+$CaCO_3$; No. 3, Nutrient sol.+$CaSO_4$; No. 4, Nutrient sol.+5 c.c. Fe sol.; No. 5, same as No. 4+$CaCO_3$; No. 6, same as No. 4+$CaSO_4$; No. 7, Nutrient sol.+2 c.c. Fe sol.; No. 8, same as No. 7+$CaCo_3$; No. 9, same as No. 7+$CaSO_4$; No. 10, Nutrient sol.+1 c.c. Fe sol.; No. 11, same as No. 10+$CaCO_3$; No. 12, same as No. 10+$CaSO_4$.

to the arresting of the development or killing of the cells in the growing portion of the root, and not to a poisoning of the entire root system. This is further shown by the large number of short roots which develop from the base of the stem and grow until they touch the toxic solution. The continued growth of the tops after the roots have become stunted also seems to point to the fact that the injury was confined to the growing tips of the roots. If internal, the tops would show the effects sooner than from four to six days after the effect is noticed on the roots. The reason the seedlings finally die is due to a lack of nourishment rather than to a poisoning of the seedling itself. Finally, as Mr. Morse has shown in the preceding article, no appreciable increase in the amount of iron is found in the roots or tops of clover plants whose poor growth in comparison with normal clover plants is assumed to be due to the toxic action of iron.

BULLETIN No. 162 MAY, 1915

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

PHOSPHATES IN MASSACHUSETTS AGRICULTURE

IMPORTANCE, SELECTION AND USE

By Wm. P. BROOKS

This bulletin shows that phosphoric acid is not relatively deficient in Massachusetts soils, and that under the systems of agriculture common in the State (which almost invariably include the use of some phosphate) there is no reason to believe that it is generally becoming more so. The general results of two series of experiments comparing different phosphates, one extending over twelve and the other over eighteen years, are presented. These results indicate that the application of at least a moderate amount of phosphate is usually profitable, and that the more soluble and available materials give results much superior to those obtained with the fine-ground rock phosphates. It is shown that the dissolved phosphates favor more rapid early growth, earlier and more perfect maturity and larger yields than the rock phosphates, and that the former are used with greater profit than the latter.

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* On leave.

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APPROVED BY

THE STATE BOARD OF PUBLICATION.

PHOSPHATES IN MASSACHUSETTS AGRICULTURE; IMPORTANCE, SELECTION AND USE.

WM. P. BROOKS.

SUMMARY.

A. In some of the corn-belt States farmers are advised that phosphorus is the key to permanent and profitable agriculture, and that fine-ground rock phosphates should be used to supply that element.

B. It is pointed out in support of this position that in the agriculture of that section the soils contain relatively little phosphorus and are being rapidly depleted in that element; that they contain practically exhaustless stores of potash; and that by suitable use of lime and the growth of legumes their need for nitrogen can be met.

C. It will be the purpose of this bulletin to show to what extent these statements apply under Massachusetts conditions.

D. It is believed that the facts and results presented will justify the following conclusions: —

1. Massachusetts soils, though not usually supplying as much phosphoric acid as maximum crops require, show a much less signal relative deficiency in that element than corn-belt soils.

2. In our system of agriculture our soils are not being depleted in phosphoric acid, some of the more important reasons being: —

(*a*) The products sold carry relatively little phosphoric acid.

(*b*) Purchased grain and by-products, fed largely on our farms, contain large amounts of phosphoric acid which finds its way to our soils in farm manures, since phosphoric acid, voided in the dung, does not waste appreciably between the stable and the field.

(*c*) The practice of supplementing manures with commercial fertilizers, except where the former as in some types of market gardening are applied in enormous quantities, has been for many years and is now practically universal, and as a rule these commercial fertilizers contain a high proportion of phosphoric acid.

(*d*) Phosphoric acid, even when applied in soluble forms, is fixed and retained in the soil under ordinary soil conditions. This compound is subject to little or no loss by leaching.

3. Experiments in this station and elsewhere in the State indicate that for most of our leading crops potash far more frequently than phosphoric acid is the dominant food requirement. The only prominent exceptions are the crucifers, — cabbage, turnip, etc.

4. Notwithstanding the fact that potash is usually the more important of the two the use of phosphoric acid in our agriculture is generally profitable, as will be shown by the results of experiments presented.

5. It will be shown that when both dissolved and fine-ground natural rock phosphates are annually applied the former have given both the larger and the more profitable crop increases over a long series of years.

6. It will be shown that although more than 1,600 pounds per acre of phosphoric acid in the form of natural rock phosphates have been applied in a series of experiments extending over eighteen years, the yields on these plots at present are even more inferior to the yields on plots receiving the same amount of phosphoric acid in the more soluble phosphates than in the earlier years of the experiments.

7. It will be shown that the dissolved phosphates have exerted certain highly important secondary effects, among the more important being: —

(*a*) Stimulation to rapid early growth both of root and top, which secures, among other important advantages, sufficient root growth to more surely draw from the soil from the start both the water and the food needed, and ability better to resist insect injuries.

(*b*) Earlier and more perfect maturity, which may mean a much higher price for the product, as in market gardening, or immunity from frost damage in the case of late ripening crops or cold summers.

(*c*) It will be pointed out that the work of others appears to demonstrate the following additional secondary effects following the judicious use of dissolved phosphates: increased tillering of grain and grasses; increased availability of some important soil constituents; greater activity of nitrifying organisms in the soil; and larger soil gain in atmospheric nitrogen as a result of increase in assimilation of this element by micro-organisms in the soil.

8. Results will be presented which indicate that reasonable use of an acid phosphate does not increase the necessity for application of lime, — indeed, that in the experiments cited it appears to have had the opposite effect.

9. The final conclusions drawn from a consideration of all the facts and results discussed may be thus stated: —

(*a*) In Massachusetts agriculture it usually pays to use phosphoric acid containing fertilizers in at least moderate amounts.

(*b*) The more soluble phosphates are better adapted to our needs than the fine-ground natural rock phosphates. Among materials ordinarily used for supplying phosphoric acid only, usually most available and satisfactory, are acid phosphate, dissolved bone black and basic slag meal. Almost all mixed and special complete fertilizers contain liberal amounts of soluble and available phosphoric acid. Other sources of phosphoric acid in soluble or fairly available forms are dissolved bone, bone meals, tankage and fish, all of them also supplying some nitrogen.

INTRODUCTION.

During the last few years the system in the use of fertilizers, and more particularly the practice of depending upon fine-ground rock phosphate, so strongly advocated by Dr. Cyril G. Hopkins and some others, and based largely upon experimental results obtained by Dr. Hopkins in Illinois, have been prominently advocated in some of our agricultural papers for adoption under Massachusetts conditions. At the present time a company interested in the sale of fine-ground natural phosphate is carrying on an active propaganda which aims to convince our farmers, fruit-growers and gardeners that the chief fertilizer requirement of their soils is phosphoric acid, and that fine-ground natural rock phosphate is the material best adapted to their needs. The literature sent out by this company is being distributed everywhere. The conclusions urged are supported by numerous quotations, figures and illustrations drawn chiefly from the publications of experiment stations in the great central valley — the corn-belt — of the United States. This matter is so marshalled and presented that the argument seems likely to produce a strong impression; it may carry conviction to many minds.

It is of the utmost importance to our agriculture that the extent to which the teachings of Dr. Hopkins (the father of the system) are applicable under Massachusetts conditions should be known. If he be right, then certainly our farmers are buying unnecessary fertilizer elements, and needlessly paying the fertilizer manufacturers to render the phosphoric acid of the rock phosphates soluble and available. The adoption here of the Hopkins system, if sound, must mean a more profitable agriculture.

It seems, therefore, highly important that the whole question should be most carefully studied. Local conditions must be compared with corn-belt conditions; the results of local experiments must be presented and studied. It is well known that practice must usually vary with locality. A practice wise in one section is often most unwise in another where conditions are different.

The general features of the Hopkins system are stated on page 159 of his book on "Soil Fertility and Permanent Agriculture," from which the following quotation is taken: —

> For practically all of the normal soils of the United States, and especially for those of the Central states, there are only three constituents that must be supplied in order to adopt systems of farming that, if continued, will increase, or at least permanently maintain, the productive power of the soil. These are *limestone, phosphorus* and *organic matter.* The limestone must be used to correct acidity where it now exists or where it may develop. The phosphorus is needed solely for its plant-food value. The supply of organic matter must be renewed to provide nitrogen from its decomposition and to make available the potassium and other essential elements contained in the soil in abundance, as well as to liberate phosphorus from the raw mineral phosphate naturally contained in or applied to the soil.

The value of an application of lime in some form to many of our soils is fully recognized. It is frequently an essential for successful crop production. The importance of organic matter is admitted. It is useful not alone in promoting the availability of such elements as potassium and phosphoric acid, and as a source of nitrogen to the growing crop, but also for the maintenance of satisfactory soil texture. Without a fair proportion of such matter in the soil good tilth is impossible, and on the lighter soils, especially, extreme injury to crops in periods of drouth is a certainty. These phases of the general subject of fertility will not be discussed in this paper. It is proposed simply to study the question of the applicability of the Hopkins theory in relation to the use of phosphorus[1] to Massachusetts conditions.

The quotation above cited makes it apparent that Hopkins regards the application of fertilizer nitrogen or potash under normal soil conditions as superfluous, and that he believes that a suitable application of phosphorus (in addition to lime and organic matter) is all that will be found needful.

The conclusions of Dr. Hopkins are further emphasized and the reasons therefor more clearly brought out by the following quotation from the book above referred to:[2] —

> Phosphorus is the only element that must be purchased and returned to the most common soils of the United States. *Phosphorus is the key to permanent agriculture on these lands.* To maintain or increase the amount of phosphorus in the soil makes possible the growth of clover (or other legumes) and the consequent addition of nitrogen from the inexhaustible supply in the air; and, with the addition of decaying organic matter in the residues of clover and other crops and in manure made in large part from clover hay and pasture and from the larger crops of corn and other grains which clover helps to produce, comes the possibility of liberating from the immense supplies in the soil sufficient potassium,[3] magnesium, and other essential abundant elements, supplemented by the amounts returned in manure and crop residues, for the production of large crops at least for thousands of years; whereas, if the supply of phosphorus in the soil is steadily decreased in the future, in accordance with the past and present most common farm practice, then poverty is the only future for the people who till the common agricultural lands of the United States.
>
> And this does not refer to the far-distant future only, for the turning point is already past on most farms in our older states and on many farms in the corn belt; and lands that have passed their prime with sixty years of cultivation will decrease rapidly in productive power and value during another sixty years of similar exhaustive farm practice.

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[1] Phosphorus is the element of value as plant food supplied by the compound phosphoric acid, which is the most valuable constituent of acid phosphate, dissolved bone black, basic slag meal, fine-ground rock phosphates and raw and steamed bones. In the publications of this experiment station and in agricultural literature in general the name "phosphoric acid" is usually used. Figures indicating the amounts of phosphoric acid can be converted into approximate equivalents in phosphorus by multiplying by .44; and figures for phosphorus into substantial equivalents in phosphoric acid by multiplying by 2.3.

[2] Hopkins' "Soil Fertility and Permanent Agriculture," page 183.

[3] Potassium is the name of the element of plant-food value in the compound potash or potassium oxid, under which names in our station publications and in agricultural literature in general this plant food is usually referred to. Figures for potash (or potassium oxid) can be converted into approximate equivalents in potassium by multiplying by .83; figures for potassium can be converted into potash (or potassium oxid) by multiplying by 1.2.

Some of the more essential among the reasons which Dr. Hopkins here advances in support of his system of dependence upon application of fine-ground rock phosphate are the following: —

1. Phosphorus is already dangerously deficient in the soils of our older States, and is rapidly becoming more so.

2. There are, on the other hand, in the most common soils of the United States, "immense supplies of potassium" (and other essential elements), — enough, "supplemented by the amounts returned in manures and crop residues," for the production of "large crops at least for thousands of years."

3. If limestone be first applied to neutralize existing acidity, and fine-ground rock phosphate thereafter abundantly applied, the soil will become fitted for the growth of clover (or other legumes).

4. The growth of clover makes possible the acquisition of nitrogen from the air, so that this element need not be purchased.

5. If organic matter in the residues of clover and other crops, and in manure made largely from clover hay and pasture, be abundant in the soil, the phosphoric acid of the natural rock phosphates will be rendered available with sufficient rapidity for large crop production.

6. The use of rock phosphate instead of acid phosphate or (by fair implication I think) other sources of phosphoric acid means a large saving in money outlay.

7. The results of numerous experiments which it is held prove the soundness of these conclusions are presented in the book above referred to, in bulletins of the Illinois Experiment Station, as well as in other writings by Dr. Hopkins, who in the book and to some extent elsewhere also quotes results obtained in several other experiment stations.

It is proposed to consider these propositions, as to the degree of their applicability to the conditions of our agriculture, in the light of such experimental work bearing upon them as has been done in this experiment station. The writer would call particular attention to the fact that this study is not entered upon because of any doubt of the validity and soundness of Dr. Hopkins's conclusions and advice in so far as they relate to the conditions of the corn-belt. He is at the same time an able investigator and a tireless worker. His work has been of enormous value to the farmers of the corn-belt.

Among the reasons enumerated the first and second, both of which relate to the composition of the soil, are most conveniently considered together.

RELATION OF MASSACHUSETTS AGRICULTURE TO SOIL COMPOSITION, AND RESULTS OF CHEMICAL ANALYSES.

Under the system of agriculture most common in the corn-belt States phosphoric acid is largely carried away from the farm in products sold. Wheat, corn, oats, beef, mutton, pork and milk are all rich in this compound. In view of this fact it is not surprising that, as Dr. Hopkins points out, the supply of phosphorus in the soils has decreased steadily under the system of agriculture pursued, and is now steadily decreasing under the most common farm practice.

Conditions in Massachusetts are widely different: —

1. The principal products sold from our farms are hay, vegetables, fruit and milk. The latter is the only product which carries away much phosphoric acid, and the proportion in this is small. The milk of 20 cows for one year (6,000 pounds each) will contain only about 100 pounds of phosphorus.

Timothy hay contains over four times as much potash as phosphoric acid; medium red clover, five times; cabbages, four times; potatoes, six times; and other vegetables in about the same proportion. In fruits the amount of potash is about six times the amount of phosphoric acid. If we reduce these figures to the basis of phosphorus and potassium used by Hopkins the comparison is yet more striking, for in the products chiefly sold from Massachusetts farms the amount of potassium carried away will run from eight to ten times the amount of phosphorus.

2. Many farmers use a large amount of purchased feeds, nearly all of which are very rich in phosphoric acid. This reaches our soils in the manures from our cattle and horses. In the oats fed on the average to a pair of work horses in one year there are about 40 pounds of phosphoric acid, while in the purchased feeds for a herd of 20 cows it is probable that on the average we shall find 600 pounds of phosphoric acid.

3. The potash of animal excrements is voided mostly in solution in the urine (on the average, about four-fifths of the total). The phosphoric acid, on the contrary, is voided almost exclusively in the dung in insoluble forms. Under ordinary systems of stabling our live stock and saving manures the potash, therefore, is subject to loss in much greater degree than the phosphoric acid.

4. That the crops we principally grow take from our soils far more potash than phosphoric acid has been made apparent from what has been said of the relative proportions of these two elements in the products sold. Essentially the same relation holds for the products mainly consumed on the farm.

5. In our agriculture we have used commercial fertilizers largely for at least forty years. With few exceptions these contain much larger proportions of phosphoric acid than of potash. It is impossible to present exact figures, but it is the writer's judgment that on the average twice as much phosphoric acid as potash has been generally applied in the fertilizers used.

Does it seem likely, in view of the facts stated, that our soils are being especially depleted in phosphoric acid? This can be true only if the phosphoric acid is subject to loss from our soils under the influence of natural agencies in unusually large proportion. That this is the case is highly improbable. Phosphoric acid cannot escape into the air; and in the soil, even though soluble when applied, it soon enters into new combinations insoluble in water. Experiment shows that under normal conditions there is but very little loss of phosphoric acid in drainage waters.

Does it, then, seem probable that in Massachusetts agriculture, as in that of the corn-belt, phosphoric acid is the only mineral element which need be supplied?

The principal conditions having a bearing upon the tendency in our farm practice may be thus restated: —

1. In products sold from five to six times as much potash as phosphoric acid is carried away.
2. We bring in large amounts of phosphoric acid in purchased feeds.
3. Potash is far more subject to waste from animal excrements than is phosphoric acid.
4. The products of our fields, gardens and orchards all require far more potash than phosphoric acid.
5. In the commercial fertilizers so extensively used far more phosphoric acid than potash has been for years applied to our soils.

The tendency in our agriculture, therefore, must be to disproportionate consumption of potash and not of phosphoric acid.

If, however, the stock of phosphoric acid in our soils is extremely small, — far less than the stock of potash, — then it may nevertheless be true that phosphoric acid rather than potash is the principal fertilizer requirement in our agriculture.

A study of the results of such analyses of our soils as have been made is essential to the formation of a conclusion upon this point.

Composition of Massachusetts Soils.

This experiment station has published the results of analyses of 194 soil samples[1] taken in this State. These samples have come from 79 different towns and represent practically all our leading soil types. All the counties of the State except Dukes and Nantucket — the island counties — are represented.

The analyses reported have been made by the methods recommended by the American Association of Official Agricultural Chemists. These methods do not show the totals of any of the plant-food elements except nitrogen, but only the proportion which is dissolved in an acid of definite strength used at a definite temperature for a definite length of time. The results are believed to represent at least the percentages likely to become available within a generation. The table shows the average results by counties and for the entire State.

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[1] See twenty-third annual report, Massachusetts Agricultural Experiment Station, p. 339.

Soil Analyses.

COUNTY.	Number of Towns represented.	Number of Samples.	N.	P_2O_5.	K_2O.	CaO.
Barnstable,	2	2	.205	.145	.170	.695
Berkshire,	3	8	.286	.242	.452	.856
Bristol,	5	16	.198	.147	.180	.643
Essex,	6	13	.518	.251	.295	.544
Franklin,	8	16	.352	.212	.306	.718
Hampden,	7	23	.253	.390	.310	.837
Hampshire,	6	21	.259	.215	.236	.704
Middlesex,	15	33	.256	.143	.213	.618
Norfolk,	8	19	.276	.187	.187	.916
Plymouth,	7	17	.312	.175	.197	.655
Suffolk,	1	9	.213	.140	.247	.416
Worcester,	11	17	.258	.250	.295	.713
Average (194 samples),	79	194	.282	.214	.252	.669

Examination of the table shows that there are but two counties in which the percentage of potash exceeds that of phosphoric acid by any considerable amount, — Berkshire and Franklin. In Berkshire there is about 90 per cent. more potash than phosphoric acid; in Franklin, about 44 per cent. more. The soils analyzed from Berkshire County have all come from three towns, — Lenox, Washington and North Adams. Those from the two former are of about the usual character, but those from North Adams are unusually rich in potash.

Eight different towns are represented in the Franklin analyses. The samples excessively rich in potash are more generally distributed. Nearly every town shows samples in which the per cent. of potash is nearly or quite double that of phosphoric acid.

The average for the State shows the proportion of the two compounds, phosphoric acid and potash, to be nearly equal, — .214 per cent. phosphoric acid and .252 per cent. potash. These figures pertain to the surface soil, the depth of which, of course, varies greatly. Assuming, however, that the average depth is 8 inches, and that the average weight of surface loams is about 80 pounds to the cubic foot, the total number of pounds of surface soil in an acre is approximately 2,300,000. The table below shows in round numbers the number of pounds each of phosphoric acid and potash in an acre of the average composition of Massachusetts soils, and for comparison the number of pounds, in most cases as indicated by analyses made here, of each of these compounds contained in the supposed product of one acre of some of our leading crops: —

	Pounds in One Acre Surface Soil (8 Inches).	Corn; Grain, 75 Bushels; Stover 3 Tons.	Potatoes, 300 Bushels.	Timothy Hay, 2.5 Tons.	Cabbages, 20 Tons.	Onions, 800 Bushels.	Tomatoes,[1] 500 Bushels.	Asparagus, 6,000 Pounds.
Phosphoric acid (pounds),	5,000	47.26	13.68	17.10	8.00[2]	29.12	21.00	6.40
Potash (pounds), . .	5,800	107.28	91.80	73.00	136.00	74.88	105.00	20.00

[1] From Van Slyke, "Fertilizers and Crops."

[2] Most published analyses are higher for this constituent.

The totals for phosphoric acid and potash in the surface 8 inches of the average Massachusetts soil (as determined by analyses which have been made here), and shown in this table, may be compared with the requirements of large crops, also shown in the table. This comparison, made by dividing the totals in the soil by the totals in the crops, shows that there is phosphoric acid enough in the soil for from 92 to 800 crops. The potash is sufficient for from 42 to 290 crops. It is, of course, not the writer's belief that without manure or fertilizer profitable crops can be grown for the number of years which this method of calculation shows; for long before the supply of phosphoric acid or potash should become exhausted the yield would fall below the limit of profitable production; indeed, on many of the soils included in arriving at the averages presented, profitable production without the addition of both phosphoric acid and potash in manures or fertilizers is already impossible. Plants cannot "lick the platter clean."

It is generally known that the root system is by no means confined to the surface soil. Where the water table allows, most crops feed to some extent to the depth of several feet. The relation of total phosphoric acid and potash in surface soil to the amount in crops is nevertheless of interest in connection with our consideration of the applicability of the Hopkins theory of farm fertility under our conditions. The facts cited strengthen the writer's contention that potash rather than phosphoric acid is the key to profitable agriculture in most cases in Massachusetts.

RELATIVE NEED OF PHOSPHORIC ACID AND POTASH.

Experimental Results.

Full details will not be given in this paper. They will be brought together for publication in a bulletin on "Potash Requirements in Massachusetts Agriculture." Detailed reports on results from year to year in most of the experiments to which reference will here be made have appeared in bulletins and annual reports of the station.

The Potato. — The experiments which have been in progress for so many years for comparison of different phosphates, and those for the comparison of different potash salts, make it possible to compare the effects of phosphoric acid and of potash. In each case the average increase of all the plots receiving in the one case phosphoric acid, and in the other potash, is compared with the average of the no-phosphoric acid or the no-potash plots. There are 3 no-phosphate plots and 10 receiving phosphate in the one experiment; and in the other there are 5 plots which receive no potash and 35 which do receive it. The table shows the results: —

Potatoes — Relative Effects, Phosphoric Acid and Potash.[1]

	Average Yield per Acre (Bushels).	Increase.	
		Per Acre (Bushels).	Per Cent.
Fourteenth Year (1910).[2]			
No-phosphate plots,	248.4	7.7	3.09
Phosphate plots,	256.1		
Tenth Year (1907).[3]			
No-potash plots,	197.96	57.21	29.39
Potash plots,	255.17		
Sixteenth Year (1913).[4]			
No-potash plots,	41.20	49.47	120.55
Potash plots,	90.67		

The station has carried out a few co-operative soil tests with potatoes as the crop. The results of four of these, located respectively in Marblehead, Hadley, Concord and Amherst, have been averaged, and in so far as they serve to indicate the relative need for phosphoric acid and potash for this crop the averages are here presented.[5] As is customary in soil test work[6] each plant-food element is used by itself, in combination with each of the others and in combination with both of the others. Averages will be presented showing the results of the two elements under comparison when used alone, as well as when each is used in connection with both the others. The latter figures, as will be understood, are the more significant, as each element may more fully show its effect and importance when all others are present in sufficient amounts.

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[1] The number of the years as given indicates length of time the fertilizer experiment had continued. Crops have always been rotated.

[2] For details see twenty-third annual report, Part I., pp. 42-44.

[3] For full details see twentieth annual report, Part I., pp. 39-42.

[4] From unpublished results. The very small yield in this year was due chiefly to seasonal peculiarities.

[5] For details see Bulletin No. 18, Hatch Experiment Station.

[6] The plan followed in this soil test work, as well as in all the other similar work referred to in this bulletin, is given in Bulletin No. 9 of the Hatch Experiment Station.

Average Increases per Acre in Potato Crop (Bushels).

	Produced by the Use of —	
	Phosphoric Acid.	Potash.
When used alone,	8.68	43.54
When used in complete fertilizer,	7.94	60.39

The Corn Crop. — The corn crop has been used in soil test work in this station far more extensively than potatoes, and the results bear very decisively upon the question of the relative necessity of application of phosphoric acid and potash in our agriculture. In the experiments upon the south soil test acre, which have been continued from 1889 to the present time, ten corn crops have been grown.[1] The average results are shown in so far as they bear upon the question under discussion in the tables which follow: —

Average Increase per Acre in Nine[2] Corn Crops (South Soil Test).

	Produced by the Use of —			
	PHOSPHORIC ACID.		POTASH.	
	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).
When used alone,	1.7	—39.0	26.3	2,043.3
When added to nitrate,	2.7	212.0	20.8	1,748.8
When added to the other,[3]	6.3	534.4	30.9	2,616.7
When used in complete fertilizer,	14.2	911.7	32.5	2,447.2

The crop in this field in 1913 was corn following crimson clover sown in 1912 and plowed under in the spring of 1913. The crop where phosphoric acid alone had, then, been yearly applied for twenty-five years (lime in 1899, 1 ton per acre; 1904, 1 ton per acre; and 1907, ½ ton per acre excepted) was at the following rates per acre: grain, 11 bushels (10 of which were soft), and stover, 2,180 pounds. Where potash had been used alone for the same number of years and under the same conditions the yield was grain, 52.6 bushels (7.7 of which were soft), and stover, 4,360 pounds.

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[1] For full reports see bulletins and reports of the Massachusetts Agricultural Experiment Station (known as the "Hatch" Experiment Station, 1888 to 1906).

[2] The crop for 1910 is not included in figuring averages, since through accident the appropriate fertilizer was not applied in that year to one plot.

[3] That is, phosphoric acid added to potash or potash added to phosphoric acid.

The comparative results with corn surely show in a most striking way the paramount importance of potash for that crop on this soil, while it is brought out with equal clearness that the effect following the application of phosphoric acid is comparatively insignificant. It is pertinent here to call attention to the fact that the field in which these experiments have been tried is of the same character, both as to geological origin and past treatment, as the soils for which analyses showing extraordinary quantities of potash both in surface and subsoils have been made. An analysis of this soil has shown it to contain .38 per cent. acid soluble potash in the surface soil, which undoubtedly means at least 40,000 pounds total potash in the first 3 feet in depth to the acre.

It will be of interest here to inquire whether similar results should be anticipated with the corn crop in other parts of the State. The station has conducted thirty-one soil test experiments with corn in different parts of the State, every county, except Dukes and Nantucket (islands), and most of the leading soil types being covered. With hardly an exception the results have been of the same general character with those on our own grounds, and in full agreement with those as to general teaching. A few averages only will be here presented.[1]

Average per Acre in Thirty-one Corn Crops (Soil Tests).

	INCREASE PRODUCED BY THE USE OF —			
	PHOSPHORIC ACID.		POTASH.	
	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).
When used alone,	.75	8.84	10.85	902.04
When used in complete fertilizer,	5.91	265.72	12.75	1,402.57

These results, while not demonstrating so great a degree of superiority for the potash as compared with the phosphoric acid as our home experiments, still indicate that it, rather than phosphoric acid, is the element chiefly required.[2]

The Hay Crop. — A good basis of comparison of the effects, respectively, of phosphoric acid and potash upon this crop is afforded by the results upon the fields devoted to comparative trials of different phosphates (phosphate field) and of different potash salts (field G). The hay crop included in the rotations which have been followed on both has included mixed timothy, redtop and red and alsike clovers. On the phosphate field materials furnishing nitrogen and potash are annually equally and liberally applied to all plots. There are 3 no-phosphate plots and 10 receive phosphoric acid. On field G there are 5 similar series of plots, each series including 1 no-potash plot and 7 receiving potash. All plots annually receive materials furnishing equal nitrogen and phosphoric acid. Average results only are here presented.[1]

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[1] For details see Bulletins Nos. 9 and 18, Hatch Experiment Station, and annual reports.

[2] In our soil test experiments dissolved bone black or acid phosphate at the rate of 320 pounds per acre has always been used as the source of phosphoric acid, and muriate of potash at the rate of 160 pounds per acre as the source of potash. It is recognized that in using these amounts we are applying potash at a heavier rate per acre than phosphoric acid, — about 80 pounds to about 54 pounds. It is pointed out, however, that while the ratio of application of phosphoric acid to potash is as 1 : 1.5, the ratio of these elements in the crop is 1 : 6.7, so that phosphoric acid is applied in much the larger proportion as compared with the crop requirement.

Effects of Phosphoric Acid on the Hay Crop (Phosphate Field).

Year.	Yields per Acre (Pounds).				Gain.			
	No phosphate.		Average phosphate.		Per acre (pounds).		Per cent.	
	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.
1906, . . .	6,720	1,867	7,308	1,944	588	77	8.7	4.1
1907, . . .	7,933	333	8,612	480	679	147	8.5	44.0

Effects of Potash on the Hay Crop (Field G).

Year.	Yields per Acre (Pounds).				Gain.			
	No potash.		Average potash.		Per acre (pounds).		Per cent.	
	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.
1909, . . .	5,744	680	6,413	1,561	669	881	11.6	129.6
1910, . . .	6,240	698	6,829	1,685	589	987	9.4	141.4
1911, . . .	3,040	1,440	4,283	1,908	1,243	468	40.9	32.5

It will be noted that neither phosphoric acid nor potash produced a large increase in the first cut of the season ("hay") except in one year, 1911, when the potash appeared greatly to improve the crop. Neither, as is well understood, is the dominant requirement for either timothy or redtop which predominate in the first cut. The increase in hay produced by the potash is, however, greater even when lowest than that produced by the phosphoric acid at its best.

The far greater proportional increase in the rowen crop produced by the potash is explained by its relation to clover, which cannot be successfully produced in our soils without it. The lesser increase in the rowen crop in 1911 is doubtless explained by the fact that the original clover plants (biennial or short-lived perennials) had then for the most part died, that being the third year since seeding.

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[1] For details see annual reports for 1907, 1908, 1910, 1911 and 1912. The great variations in yield, even with full fertilization in different years, were doubtless due chiefly to seasonal variations in rainfall.

The soil test work of the experiment station affords another opportunity of comparison of the effects of phosphoric acid and potash on the hay crop (as in the other experiments with hay referred to made up of timothy, redtop and clovers). Hay has occupied our south soil test acre six years, but in only four of them was a second or rowen crop cut. The soil is rather light, the fertility only medium, even on the plots receiving a complete fertilizer, and in hot, dry summers the second growth is light.

Average Increase in Six Hay and Four Rowen Crops (South Soil Test) (Pounds).

	Produced by the Use of —			
	PHOSPHORIC ACID.		POTASH.	
	Hay.	Rowen.	Hay.	Rowen.
When used alone, ...	—66.7	78.8	407.1	489.5
When used in complete fertilizer, . . .	463.3	367.5	721.7	607.5

The striking superiority in effects produced by the potash is at once apparent.

Results obtained in soil tests in different parts of the State are similar in kind, but the superiority of the yields on potash is much smaller than on our home grounds, — a consequence, in my judgment, at least in large measure, of the fact that the soils were undoubtedly in many cases acid. These experiments were all tried before the fact that so many of our soils are in need of lime was fully appreciated (1892 to 1895).

Asparagus. — We have definite data on asparagus. In our substation in Concord for asparagus investigation both phosphoric acid and potash are applied — in combination in each case with the other two plant-food elements — under conditions which make it possible to determine the specific effects. Each of the plots for which data are given has been under uniform treatment for seven years. The phosphoric acid is applied in the form of acid phosphate, and the potash in the form of muriate. The table presents the relative results of the application of phosphoric acid and potash for 1914 (the seventh year).

Asparagus — Comparative Results, Phosphoric Acid and Potash, 1914.
(Yield and Increase per Plot.[1])

Acid Phosphate.

Amount applied per Plot (Pounds).	Yield.		Increase.	
	Pounds.	Ounces.	Pounds.	Ounces.
None,	404	4	-	-
15.00,	420	6	16	2
22.50,	436	15	32	11
30.00,	436	6	32	2

Muriate of Potash.

Amount applied per Plot (Pounds).	Yield.		Increase.	
	Pounds.	Ounces.	Pounds.	Ounces.
None,	366	11	-	-
8.67,	408	6	41	11
13.00,	478	15	112	4
17.33,	458	8	91	13

[1] One-twentieth of an acre.

The objection may possibly be raised — as in the case of the soil test work, in which some of the results cited for corn and other crops were obtained — that the potash being used at a greater rate per acre than the phosphoric acid, the comparison may be misleading. If, however, phosphoric acid be the element present *in minimo*, certainly even a very moderate application should give a notable increase in crop; and further, if it be the element *in minimo* and our application be too small, no amount of potash could exercise much effect, for it cannot take the place of phosphoric acid.

Yet further, in view of the facts that the ratio of phosphoric acid to potash is 1 to 3 in the crop (spring shoots), while in our applications the ratio between the two is 1 to 1.9, it can scarcely be urged that we are using phosphoric acid in disproportionately small amounts.

Soy Beans, Oats and Rye. — Soil test experiments with soy beans have given much larger increases in crop with potash than with phosphoric acid. Similar experiments with oats and rye have shown a relatively small superiority for the potash. Neither is the dominant element for these crops.

Cruciferæ. — Absolutely the only crops which have ever responded in our soil test work more largely to an application of phosphoric acid than to one of potash are those belonging to *Cruciferæ*, such as the cabbage, Swedish turnip and white mustard.[1] This is best shown in the results obtained on the north soil test in 1896 with cabbages. With Swedish turnips in that year the two materials gave equal increases.

Cabbages and Turnips — Increases per Acre (North Soil Test) (Pounds).

	Produced by the Use of —			
	PHOSPHORIC ACID.		POTASH.	
	Cabbage.	Turnip.	Cabbage.	Turnip.
When used in complete fertilizer, . . .	20,890	10,400	14,400	10,400

The experimental results presented appear to prove that potash application may usually be depended upon to give greater increases in most of our more important crops than phosphoric acid application. The figures given very conclusively demonstrate this for our station grounds, and, with little less conclusiveness, for widely divergent soil types in most parts of the State for potatoes, corn, hay (especially the second cut, which is usually chiefly clover) and soy beans. We know that the requirements of other legumes, including alfalfa, are in general similar to those of clovers and soy beans. We know, also, that potash application exercises a far greater effect in determining the yields of most of our fruits and garden crops than phosphoric acid application.

In view of the fact so clearly demonstrated by the figures which have been presented for our most important crops, no further argument would seem to be needed to demonstrate that phosphoric acid is not the key to "permanent" (successful and profitable) "agriculture" in Massachusetts. It is true, indeed, that our soils and subsoils contain less phosphoric acid than potash, but it is also true that under our system of agriculture the phosphoric acid has not apparently been undergoing exhaustion, and that it is not now being depleted. It is not true for most crops that phosphoric acid is the element present in our soils *in minimo.* Potash for many is the element which determines the crop more largely than any other element applied. Without the application of potash in available form, either in manures or fertilizers, the profitable production of most crops is impossible.

On the other hand, profitable crops of most kinds may be produced for a time without application of phosphoric acid. This, indeed, is not a practice which can be recommended. Such a system should be followed as will at least maintain the proportion of phosphoric acid at present existing in our soils. To reduce the percentage below its present level would for most soils and crops be a mistake.

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[1] For discussion of this subject see Bulletin No. 58, Hatch Experiment Station.

Massachusetts farmers, then, should apply phosphoric acid for most crops, but certainly not to the exclusion of potash. However abundant the phosphoric acid it will not take the place of potash. However largely applied it will not reduce the necessity for the application of potash for most crops. It has no direct influence, so far as known, on the extent to which inert soil potash is rendered available. Since, however, without doubt some phosphoric acid should be applied in our ordinary farm and garden practice, the question whether, as Hopkins and his disciples believe, fine-ground rock phosphate is the best form is important. Two series of experiments in this station throw light upon the question. Both have been carried out on medium silt loams containing an average per cent. of humus and possessing excellent physical characteristics.

EXPERIMENTS FOR COMPARISON OF DIFFERENT PHOSPHATES.

The two sets of experiments designed to show the comparative effectiveness and value in agriculture of different phosphates which have been conducted here have both extended over a considerable number of years, and the conditions have been, so far as can be judged, as favorable to the activity of the more insoluble materials as will usually be found in our upland soils. The soil structure and texture are such as to favor optimum moisture conditions, and at the same time adequate aeration and good tilth. In both fields the soils were at the outset moderately acid. In the first mentioned lime at the rate of a ton to the acre was applied once during the progress of the experiment. In the other two, similar applications of lime have been made. The quantity in both fields was considerably short of that required to completely neutralize the free acids present.

In both experiments most of the principal crops common in our agriculture have found a place, and some of them for several years. In neither series of experiments has any manure been applied. In both, chemical fertilizers containing nitrogen and potash in quantities believed to be adequate for large crops have been equally applied to all plots.

In one series of experiments the basis of comparison of the phosphates used was "equal money's worth;" in the other, "equal phosphoric acid."

Comparison of Phosphates on the Basis of Equal Money's Worth.

A full account of this experiment has already been published.[1] Detailed reference to it at this time, therefore, is unnecessary. I may go further and say that any reference to the results of this series of experiments might lead to the formation of absolutely misleading conclusions. The experiment was clearly not of such a character as to afford a fair basis of comparison between the more soluble phosphates and the rock phosphates, for, as is shown by our other series of experiments as well as by the work of others, the more soluble phosphates exert special influences which are highly important as a result of their relatively soluble condition when applied. Any advantage which may be connected with this relatively high degree of solubility is of course largely lost, in so far as the residual phosphoric acid they contain is concerned, because of the change in the soil which converts this phosphoric acid into a much less soluble form. The true way to use dissolved phosphates, as is well understood, is not to apply at any one time in great excess of the requirements of the immediately succeeding crops, but to apply as a rule annually, in the case of hoed crops at least, in quantities more nearly equal to the immediate crop requirement.

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[1] Fourteenth annual report, Hatch Experiment Station, pp. 24–28.

In this series of experiments the different phosphates under comparison (dissolved bone black, basic slag meal, South Carolina rock phosphate, Florida rock phosphate and Mona guano) were applied during only four years. The experiment was continued twelve years. During this long period of time the basic slag meal gave the greatest total crop yield; the South Carolina rock phosphate ranked next, but was followed so closely by the dissolved bone black that the difference was quite insignificant in spite of the fact that the latter was used in a manner so absolutely irrational, and applied in quantity furnishing only about one-third as much phosphoric acid as was applied in the South Carolina rock phosphate. The yields on the Mona guano and Florida rock phosphate, especially on the latter, were materially below those obtained on the dissolved bone black.

It should, perhaps, be pointed out further that this experiment was continued a number of years after the crop yield on all plots had sunk below the profitable level, while there still remained in the soil of the plots which had received the rock phosphates more than two-thirds of the large amount of phosphoric acid which had been applied. At the same time, the phosphoric acid which had been applied in the dissolved bone black had nearly all been carried away in the crops.

Phosphates compared on the Basis of Equal Annual Applications of Phosphoric Acid.

This series of experiments was begun in 1897 and is still continued. We now have the results of eighteen years. The soil is a medium silt loam which had been in grass a number of years previous to being plowed for the experiment. The soil varies somewhat in physical character in different plots, but as the variation is progressive from one end of the field to the other, and the arrangement includes a no-phosphate plot at either end and one in the middle, each phosphate being compared only with the two no-phosphate plots between which it lies, and each of these being given a weight inversely proportional to its distance, it is not believed that any injustice is done to any of the phosphates in the results as presented. The more soluble phosphate plots are at the end of the field where the soil is the more heavy.

The area of the plots is one-eighth acre, — thirteen in all.

Annual Application to All Plots.

	Rate per Acre (Pounds).
High-grade sulfate of potash,[1]	300
Nitrate of soda,[2]	364
Sulfate of ammonia,	100
Hoof meal[3] (to all no-phosphate and mineral phosphate plots),[4]	102

The various forms of bone meal all contain organic nitrogen; the steamed bone usually most. To equalize conditions hoof meal is applied to each in such quantities as are required to bring the total organic nitrogen to the same amount as is furnished by the hoof meal on the other plots.

Plant-food Elements applied.

In the materials used the annual application of plant-food elements has varied somewhat with slightly varying composition of materials. One important change has been made, viz., a 50 per cent. increase in the nitrate nitrogen and in the actual potash in 1901. The annual application per plot has been substantially constant since that date, as follows: —

Plant Food applied Annually (Pounds).

	Per Plot.	Per Acre.
Nitrogen,	11.4	91.2
Potash,	19.0	152.0
Phosphoric acid,	12.0	96.0

General Treatment.

The entire field received an application of hydrated lime at the rate of one ton per acre in 1898, and again in 1914. This was spread upon the plowed land in early spring and harrowed in.

The stock of organic matter in the soil has been maintained by turning under heavy crops, as follows: winter rye in 1901, buckwheat in 1912 and rye in 1913; and by introducing grasses and clovers, 1905 to 1907, and turning under a heavy growth of grass before late cabbage in 1908.

All fertilizers have been applied broadcast in early spring, and, except when the land was in grass, on the plowed surface and disked in.

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[1] For the first two years potash-magnesia sulfate, 400 pounds; in 1899, high-grade sulfate, 400 pounds; in 1901, potash-magnesia sulfate, 400 pounds.

[2] For the first four years 250 pounds.

[3] Tobacco dust was used by accident in place of hoof meal in 1911.

[4] To all bone-meal plots an amount to make total organic nitrogen equal.

Phosphates compared and Rates per Acre.

Plot.	Materials supplying Phosphoric Acid.	Pounds per Acre.
1	None,	–
2	Arkansas rock phosphate,[1]	376
3	South Carolina rock phosphate,	376
4	Florida soft phosphate,	364
5	Basic slag meal,	538
6	Tennessee phosphate,[2]	296
7	None,	–
8	Dissolved bone black,	522
9	Raw bone meal,	404
10	Dissolved bone meal,	432
11	Steamed bone meal,	380
12	Acid phosphate,[3]	500
13	None,	–

[1] Apatite used in 1897–1905; Arkansas since 1908.

[2] Navassa phosphate used in 1897–1900; Tennessee since 1901.

[3] Owing to a clerical error in copying, which occurred in 1901, this phosphate was used only at the rate of 380 pounds per acre from 1901 to 1913, inclusive.

Crops Grown.

As already stated, the field had been continuously in grass for a long period of time previous to the beginning of this experiment. While in grass it had, during the latter part of this period at least, received moderate annual top-dressings of chemicals. The year previous to the beginning of the experiment it was plowed and planted to corn without fertilizer, with a view to noting the relative productive capacity of the different plots. The date of planting was June 27; the date of harvesting, September 26, the corn being in milk. The yields were as follows: —

Yields of Corn without Fertilizer, 1896.

Plot.	Gross Weight (Pounds).	Plot.	Gross Weight (Pounds).
1,	3,440	8,	2,905
2,	3,090	9,	2,885
3,	3,000	10,	3,555
4,	3,095	11,	2,915
5,	3,160	12,	2,990
6,	3,020	13,	2,640
7,	2,850		

It will be noted that with three exceptions the yields are quite uniform. Plots 1 and 10 are considerably above the average in productiveness, while plot 13 is about as much below.

The crops grown during the experiment in the order of their succession have been as follows: corn, cabbages, corn, oats and Hungarian grass (in 1900), onions, onions, cabbages, corn (ensilage), grasses and clovers seeded in spring (no crop harvested), hay, hay, cabbages, soy beans, potatoes, oats and alfalfa (badly winterkilled, 1911–12), buckwheat (turned under), corn and corn.

Many of the annual crop yields have been published in the reports of the experiment station, and certain averages only will be presented at this time. These will include an average for each crop on each of the three classes of phosphates into which those used somewhat naturally fall. The first class includes the natural mineral phosphates: apatite and Arkansas phosphate,[1] South Carolina rock phosphate, Florida soft phosphate and Navassa and Tennessee phosphates;[2] the second class includes basic slag meal, raw bone meal and steamed bone meal; the third class, dissolved bone black, dissolved bone meal and acid phosphate.

The yields for the first two years have not been included in figuring these averages, as it is apparent that initial inequalities in productive capacity exercised a considerable influence in determining yields. It is not unlikely that such inequalities continued for some time (possibly they still continue to exercise some influence), but it is believed that the manner of computing increases due to the several phosphates previously described[3] has so reduced the influence of such inequalities that the averages of results extending over so long a term of years present a reliable basis for determining the relative crop-producing value of the different classes of phosphates.

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[1] Apatite from 1897–1905; since 1908, Arkansas.

[2] Navassa phosphate from 1897–1900; since 1901, Tennessee.

[3] See p. 148.

Increases per Acre in Crops produced by Different Classes of Phosphates.

	Natural Mineral Phosphates.		Basic Slag and Bone Meals.		Dissolved Phosphates.	
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.
Corn, three years, 1899, 1913, 1914: —						
Grain, ...	—1.06	–	8.03	–	9.96	–
Stover, ...	–	318.87	–	905.50	–	651.11
Hay, two years, 1906, 1907: —						
Hay, ...	–	398.30	–	615.55	–	753.33
Rowen, . . .	–	—131.00	–	97.33	–	350.67
Total, ...	–	267.30	–	712.88	–	1,104.00
Onions, two years, 1901, 1902: —						
Sound, ...	—30.60	–	143.60	–	136.73	–
Scallions, . . .	10.76	–	—19.23	–	—12.56	–
Cabbage, two years, 1903, 1908, ...	–	9,817.50	–	21,026.60	–	18,758.60
Oat hay, one year, 1900, .	–	231.70	–	1,324.40	–	1,520.00
Hungarian hay, one year, 1900, ...	–	166.70	–	—222.23	–	—253.30
Ensilage corn, one year, 1904, ...	–	—1,638.70	–	7,608.90	–	7,361.30
Soy beans, one year, 1910: —						
Grain, ...	.77	–	4.09	–	3.87	–
Straw, ...	–	290.56	–	794.67	–	776.00
Potatoes, one year, 1910: —						
Marketable, . . .	—10.70	–	16.40	–	26.90	–
Total, ...	—8.30	–	18.90	–	29.50	–
Oat and alfalfa hay, one year, 1911, . .	–	80.00	–	1,626.67	–	1,560.00
Alfalfa hay, one year, 1911,	–	91.70	–	244.40	–	73.30

The table makes it strikingly apparent that the natural mineral (rock) phosphates used in this series of experiments have produced much smaller average increases in crops than those of the other classes. For the purpose, however, of bringing out the relative effects more clearly the results have been figured on a percentage basis shown in the table below: —

Phosphate Field, 1899–1914. Increase over No-Phosphate Plots in Per Cent.

	Natural Mineral Phosphates.	Basic Slag and Bone Meals.	Dissolved Phosphates.
Corn, three years: —			
Grain,	—1.48	12.89	17.03
Stover,	5.83	17.74	13.22
Hay, two years: —			
Hay,	5.28	8.38	10.41
Rowen,	—11.34	8.64	31.88
Total,	3.08	8.42	13.24
Onions, two years: —			
Sound,	—17.75	137.35	160.10
Scallions,	12.86	—25.04	—16.56
Cabbage, two years (total),	116.01	288.30	278.32
Oat hay, one year,	4.22	27.62	33.63
Hungarian hay, one year,	4.30	—5.68	—6.46
Ensilage corn, one year,	—4.42	25.99	28.00
Soy beans, one year: —			
Beans,	2.54	14.38	14.00
Straw,	10.43	35.88	38.26
Potatoes, one year: —			
Marketable,	—4.00	6.84	11.72
Total,	—2.97	7.49	12.12
Oats and alfalfa hay, one year,	2.00	47.28	49.37
Alfalfa hay, one year,	11.49	32.35	9.40

1. The tabulation of averages shows that, with one exception, the percentage increases in crops of all kinds produced by the natural mineral phosphates are far smaller than those produced by the other classes of phosphates. The single exception is Hungarian hay grown as a second crop in 1900 without a second application of fertilizers. This exception, therefore, has no special significance in its bearing upon the relative efficiency of the classes of phosphates under consideration.

2. It will be noted that in a number of cases the averages for the slag and bone meals are higher than for the dissolved phosphates. It should be pointed out that in two respects the materials in the former class differ from those in the latter: (1) the slag meal furnishes some free lime and a considerable excess of lime in neutral combinations; (2) the bone meals supply some nitrogen in organic combinations.

It has been pointed out[1] that an attempt to equalize the organic nitrogen of the bone meals was made by the addition of hoof meal to the plots receiving other phosphates. It is generally held that the availability of the organic nitrogen in bone meals and in hoof meal is substantially equal, but in some experiments this has not seemed to be the case. No doubt the availability in both is much affected by fineness of grinding.

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[1] See p. 149.

No effort was made to equalize the lime supply on the different plots, although the fact that the entire field was limed twice at the rate of a ton to the acre as already described[1] reduces the probability that the excess of lime in the slag exercised an important influence. The possibility, however, that the occasional superiority of the slag and bone meals may have been due to the factors referred to should not be overlooked.

3. It should be noted that the more soluble phosphates, while not increasing the stover of the corn crop so largely as the slag and bone meals, exercise a more favorable influence upon the production of grain.

4. This is doubtless, at least in part, due to the fact that the more soluble phosphates promote more rapid early growth and earlier maturity than do those less soluble.

(*a*) *More Rapid Early Growth.* — The marked effect of an application of soluble or quickly available phosphates upon the early growth of the corn crop has been many times observed.[2] We have made measurements only once in this series of experiments, viz., in 1914. These measurements were made on July 10, and indicate the extreme height from the ground to the highest leaf-tip. The figures are the averages of 40 plants in each plot, — equidistant individuals each in the fourth and seventh rows.

Height on July 10.

Plot.	FERTILIZER.	Inches.	Plot.	FERTILIZER.	Inches.
1	No phosphate, . . .	32.23	8	Dissolved bone black, .	42.15
2	Arkansas phosphate, . .	28.92	9	Raw bone meal, . .	40.02
3	South Carolina phosphate,	30.83	10	Dissolved bone meal, .	38.79
4	Florida soft phosphate, .	32.62	11	Steamed bone meal, . .	40.20
5	Slag meal phosphate, .	35.67	12	Acid phosphate, . .	42.05
6	Tennessee phosphate, .	32.99	13	No phosphate, . . .	29.69
7	No phosphate, . . .	30.96			

The great superiority of the soluble phosphates and the bone meals is clearly brought out by this table, while the average measurement indicates the slag meal to be materially superior to the natural phosphates in its effect upon the early growth.

(*b*) In favorable years varieties of corn suited to the locality attain maturity on all plots; but in years with summer temperatures much below the average, or those with early autumn frosts, a part of the crop fails to ripen completely. This was notably the case in 1913, in which year the thermometer fell to 31° at 6 A.M. on September 15. The percentages of soft corn were lowest on the slag meal and dissolved bone, —

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[1] See p. 149.

[2] On our north corn acre acid phosphate has been used during the past twenty-five years at widely varying rates on different plots; in round numbers 1,100 pounds per acre on two plots, and 200 pounds per acre on two. During the first few weeks the growth on the plots receiving the larger application of acid phosphate is always far more rapid than on the other plots.

30 and 44 per cent., respectively; they were highest on the South Carolina rock, 87 per cent.; the average for all the natural rock phosphates was 63 per cent.; for the no-phosphate plots it was 71 per cent. The proportions of soft corn on the different plots were in my judgment affected by the physical differences in the soil of the plots, but there can be no doubt as to the general effect.

In 1914 the summer temperature was below the normal, but the crop was cut and shocked before frost. There was, however, some soft corn. The percentages were: no-phosphate plots, 12; natural rock phosphate plots, 9; slag, bone meal and soluble phosphate plots, 5.

5. The effect of the more soluble and available phosphates in promoting maturity is strikingly apparent, also, in the case of the onion crop grown in this series of experiments. The presence of scallions indicates imperfect maturity. Two onion crops have been grown in this experiment, — 1901 and 1902. Neither gave a satisfactory yield, and the proportion of scallions on all plots was much larger than normal, in my judgment, due in part to the fact that the field is not sufficiently heavily fertilized for the crop, and in part to the unfavorable physical characteristics which, as already pointed out, vary considerably on the different plots. The greater proportion of scallions on the rock phosphates shown in the following table is the more significant for the reason that in the plots where these were used the physical conditions were more favorable than on the other plots. The steamed bone meal, dissolved bone meal and acid phosphate plots have not been used in computing the averages shown because of the very unfavorable soil texture of these plots for the onion. The fact that the acid phosphate had been applied in only about one-half the amount needed to furnish equal phosphoric acid constituted a second reason for the omission of this plot.

Proportion of Scallions in Onion Crop (Per Cent. of Total).

	No-Phosphate Plots.	Dissolved Bone Black, Slag and Bone Meal.	Natural Rock Phosphates.
1901, ...	15	7	15
1902, ...	59	29	66

6. The relation between hard and soft heads in the cabbage crops grown in these experiments points also to the conclusion that the more soluble and available phosphates promote rapid early growth and maturity. In all cases there have been more soft heads on the no-phosphate and the rock phosphate plots than on the others. The slag plot has been among the best in the quality, solidity and weight of the crop. Full details have been published and figures will not now be given.[1]

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[1] For relative weights, soft and hard heads, see sixteenth annual report, Hatch Experiment Station, p. 136. For crop in other years see eleventh and twentieth annual reports.

Relative Profits on the Different Phosphates.

The results presented fully establish the facts of larger relative increases and in some instances superior quality of crops on the more soluble and available phosphates. Clearly, therefore, the use of such phosphates rather than the fine-ground natural rock phosphates is the part of wisdom, unless the cost of the latter is so much lower that they allow greater profit on their use than do the more soluble phosphates, in spite of the greater crop increases on the latter. The table gives the differences in value between the average annual crop increases and the average cost for the different classes of phosphates.

Gain or Loss per Acre in Crop Values compared with Cost of Phosphates.

	Natural Mineral Phosphates.	Basic Slag and Bone Meals.	Dissolved Phosphates.
Cost of phosphates,	$3 67	$3 70	$3 24
Corn, average of 3 crops, 1899, 1913, 1914: —			
Grain,	—$0 79	$6 02	$7 47
Stover,	95	2 72	1 95
Total,	16	8 74	9 42
Hay, average of 2 crops, 1906, 1907: —			
Hay,	3 19	4 92	6 03
Rowen,	— 79	58	2 10
Total,	2 40	5 50	8 13
Onions, average of 2 crops, 1901, 1902 (sound),	—15 30	71 80	68 36
Cabbage, average of 2 crops, 1903, 1908,	58 91	126 16	112 55
Oat hay, 1 crop, 1900,	1 39	7 95	9 12
Hungarian hay, 1 crop, 1900,	1 00	—1 33	—1 52
Total,	2 39	6 62	7 60
Ensilage corn, 1 crop, 1904,	—6 55	30 44	29 44
Soy beans, 1 crop, 1909: —			
Beans,	2 31	12 27	11 61
Straw,	87	2 38	2 33
Total,	3 18	14 65	13 94
Potatoes, 1 crop, 1910: —			
Merchantable,	—6 42	9 84	16 14
Small,	48	50	52
Total,	—5 94	10 34	16 66
Oats and alfalfa, 1 crop, 1911,	48	9 76	9 36
Alfalfa, 1 crop, 1911,	83	2 20	66
Total,	1 31	11 96	10 02
Annual average,	$6 21	$36 23	$34 57

The results shown in this table are overwhelmingly conclusive on the point under discussion. The values of the crop increases in all instances exceed the cost of phosphate many times more on the more soluble and available materials than on the natural rock phosphates. The latter afford, therefore, far lower profits on their use than the former.

Cumulative Effect.

The advocate of the use of the rock phosphates may at this point urge that while such phosphates are at first less effective than the more soluble and quickly available materials they will ultimately fully equal the latter. This series of experiments has now continued eighteen years, and it would seem that this result should have been already realized. This has not been the case. The more soluble phosphates, bone meal and slag, still annually exceed the rock phosphates greatly in their effect on crop yield. Such excess, so far as can be judged, is still as great as at any earlier period. The corn crop affords the best chance of comparison, having been grown in 1899 and in 1914. The increases in crop per acre in the two years are shown below: —

Corn Crop — Increases per Acre, with Different Phosphates.

	Natural Rock.		Slag and Bone Meals.		Dissolved Phosphates.	
	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).
1899, ...	—2.410	113.3	1.27	—127.8	5.03	—493.3
1914, ...	—0.175	243.3	13.27	1,808.9	15.37	1,460.0

These figures show greater increases in the corn crop on all classes of phosphates in 1914 than in 1899. Such increases, however, are insignificant for the natural rock phosphates, while for the slag, bone meals and soluble phosphates they are large. The latter excel the rock phosphates in 1914 in much greater degree than in 1899. The conclusion, therefore, seems justified that the natural agencies at work in this soil are not in any marked degree increasing the availability of the natural mineral phosphates. In the eighteen years during which this series of experiments has continued we have supplied 1,728 pounds of phosphoric acid per acre to the soil of these phosphate plots.[1] In the crops harvested from the rock phosphate plots, supposing them to have been of average composition, we have removed about 450 pounds. There has therefore been a large excess of phosphoric acid applied (about 1,275 pounds per acre), and still the amount available is insufficient to give maximum crops. The yields are far below those obtained on the slag, bone meals and dissolved phosphates.[2]

It is well understood that a large proportion of organic matter in the soil is favorable to the activity of the raw phosphates. In commenting on the results obtained in these experiments in his book "Soil Fertility and Permanent Agriculture,"[1] published in 1910, Dr. Hopkins says: ". . . no provision was made for maintaining organic matter in the soil."

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[1] Two exceptions have been noted, p. 150: plot 2, on which the shortage is 192 pounds, and plot 12 on which it is about 240 pounds.

[2] These also must have furnished phosphoric acid in much larger quantities than have been removed in the crops.

In view of the facts that a heavy crop of winter rye was plowed in in 1901, and after three years in hay (1905–07), a heavy growth of grass before late cabbage in 1908, it is believed the supply of organic matter had been well maintained. Certainly in our experience we have not only fully maintained, but actually increased, productiveness on soils of similar character by use of fertilizers only, under systems of management less favorable to the maintenance of the humus content. It is not believed there could have been a shortage of organic matter in the soil of these plots at the time when Dr. Hopkins wrote. Wishing, however, to create conditions as favorable as possible to the action of the raw phosphates, two heavy green manure crops have since been grown and plowed in, — buckwheat in 1912 and winter rye in 1913. It has been shown that in spite of this treatment not only is the increase in crops from the raw phosphates still less than from the others, but it seems to be falling still further behind.

INDIRECT OR SECONDARY EFFECTS.

The no-phosphate plots in this series of experiments have given crops which, as shown by calculation on the basis of average composition, have carried away nearly as much phosphoric acid as has been carried away in the crops of the phosphate plots. The totals of this element for these plots exceed the totals for the plots receiving no phosphoric acid, as follows: —

Phosphoric Acid in the Total Increases in Crops.

	Per Plot (One-eighth Acre) (Pounds).
Natural fine ground rock phosphates,	1.06
Slag and bone meals,	8.43
Dissolved phosphates,	8.63

If the crops on the phosphate plots have drawn upon the natural soil supply of phosphoric acid as largely as those on the no-phosphate plots, then the proportion of the phosphoric acid applied in these experiments which has been removed by the crops is extremely small, — indeed quite insignificant. As phosphoric acid is not subject to much if any loss from soils by leaching, it would seem that nearly all of this element which has been applied must still remain in the soil, even in those plots to which it has been applied in the more soluble forms.

In spite of this fact the use of the slag, bone meals and dissolved phosphates has given increases in crops which much more than cover the cost of the phosphates used as shown by the table on page 156. In view of this fact it appears probable that the benefits following their use must have been due in considerable measure, to indirect or secondary effects rather than to the direct plant-food action of the phosphoric acid they contained. One of these indirect effects — the stimulation to rapid early growth — has already been referred to.[1] There is considerable evidence which tends to show that there are several other indirect or secondary effects of importance.

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[1] Page 283.

EFFECT ON SOIL ACIDITY.

Most of the secondary effects are believed to be beneficial, but the question is frequently asked whether the use of dissolved (acid) phosphates will not exercise an injurious secondary effect through making soils sour. Those advocating the use of natural rock phosphates usually call especial attention to this effect. Thus, Hopkins says: "A third point in favor of raw phosphate, in common with bone and slag, is that it is free from acidity and has no tendency to injure the soil."[2] In the following sentence he asserts that acidity does develop from continued use of acid phosphate, but adds that it can be corrected at small expense by the use of lime.

The writer cannot point to results of chemical investigations in connection with his work which either prove or disprove the correctness of this assertion, that continued use of acid phosphate increases soil acidity. No such investigations have been undertaken. In some of his experiments, however, lime has been so applied as to afford opportunity to note the relative benefit as indicated by crop yield under otherwise similar conditions on plots over a long series of years, respectively, without and with application of an acid phosphate (dissolved bone black). If the dissolved bone black used continuously had increased acidity in any marked degree, it would follow that crops to which acid is toxic would show greater benefit from liming on the plots to which dissolved bone black was annually applied than on those plots not receiving it. In a long-continued series of soil test experiments,[3] where one-half of all plots has been limed, this

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[1] See p. 154.

[2] "Soil Fertility and Permanent Agriculture," p. 242.

[3] This series of experiments was begun in 1890 and has continued to date. Nitrate of soda, dissolved bone black and muriate of potash have each been applied annually, as shown by the table.

PLOT.	Materials applied.	Rates per Acre (Pounds).
1,	Nothing,	–
2,	Nitrate of soda,	160
3,	Dissolved bone black,	320
4,	Nothing,	–
5,	Muriate of potash,	160
6,	Nitrate of soda, Dissolved bone black,	160 320
7,	Nitrate of soda, Muriate of potash,	160 160
8,	Nothing,	–
9,	Dissolved bone black, Muriate of potash,	320 160
10,	Nitrate of soda, Dissolved bone black, Muriate of potash,	160 320 160
11,	Plaster,	400
12,	Nothing,	–

In 1899 one-half of all plots received an application of lime at the rate of one ton per acre; in 1904 a second application was made to the same halves at the rate of 2,300 pounds per acre; and in 1907 a third application at the rate of 1,000 pounds per acre.

has not been the case. The benefits following liming are with all crops greater without dissolved bone black than under otherwise similar treatment with it. In other words, the use of dissolved bone black appears to have decreased the necessity for lime.

Need of Lime as indicated by Relative Crop Increase after Liming.

	Muriate of Potash.		Nitrate of Soda and Muriate of Potash.	
	With Bone Black.	Without Bone Black.	With Bone Black.	Without Bone Black.
Corn, 1905: —				
Grain,	100	365	100	192
Stover,	100	1,363	100	36
Hay, four years, 1903, 1904, 1908, 1909,	100	207	100	101
Soy beans, three years, 1906, 1910, 1911: —				
Grain,	100	350	100	108
Straw,[1]	100[2]	32[2]	100[2]	90[2]

[1] Compared on the basis of relative decrease.

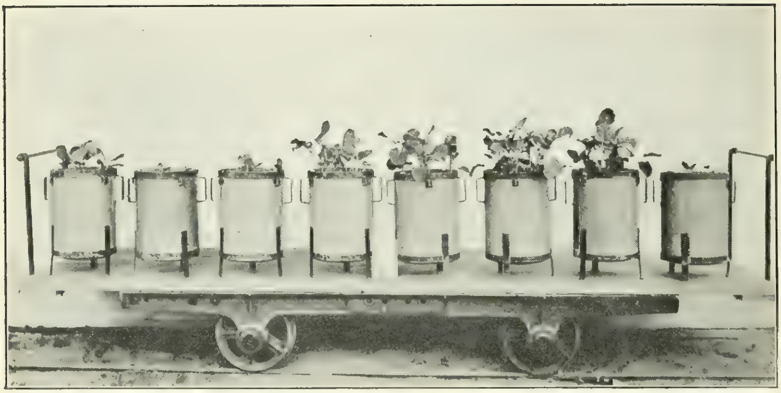
[2] Relative decrease where lime was applied.

It must be remembered in studying this table that the increases (or decreases) compared are, first, those under the treatments indicated by the headings of the first and second columns of figures; and second, those indicated by the headings of the third and fourth columns. The figures do not indicate the relations between these two pairs of plots (plots 5 and 9 and plots 8 and 10). It will be noticed that with one exception these results are perfectly concordant. The use of lime produces, with this one exception, a larger increase (or a smaller decrease) when used without dissolved bone black than when used with it. The exception is the effect upon the stover of the corn crop on nitrate of soda and muriate of potash. No explanation can at this time be offered; but it is made quite apparent by the smaller relative increases (and the larger relative decrease in one case) produced by lime without bone black when the latter is added to nitrate of soda and muriate of potash than when it is added to muriate of potash alone that the soda of the nitrate decreases the necessity for lime, — a fact which is generally understood.

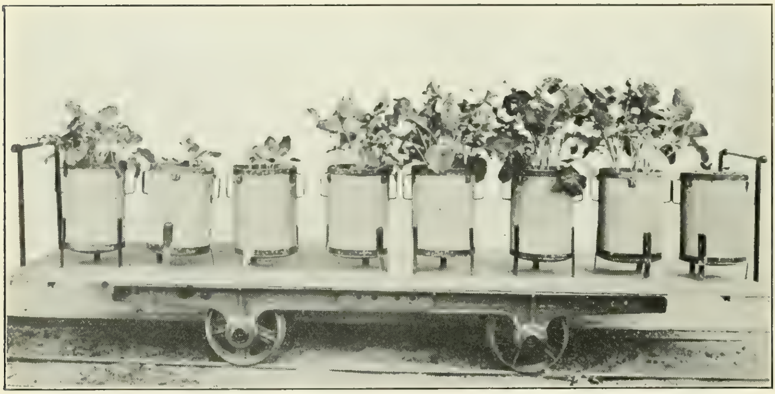
It would seem to be thoroughly established by the results of these experiments that the use of an acid phosphate (dissolved bone black) at least has not increased the necessity for lime. On the contrary, it seems clear that the bone black has reduced this necessity.

Sulfur supplied.

It is recognized that considerable quantities of sulfur, in the form of calcium sulfate, have been applied to the plots receiving dissolved phosphates, and that the plots with which these have been compared have



Comparative test of phosphates, Dwarf Essex rape. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .41 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).



Comparative test of phosphates, Dwarf Essex rape. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .82 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).

received no such application. It may possibly be urged that this sulfur has been beneficial. This of course is possible, although numerous other lines of experiment carried on by the writer which afford opportunities for comparison fail to demonstrate any necessity for the application of sulfur.

Beneficial Secondary Effects from the Use of Soluble Phosphates.

Among secondary effects which appear to be generally admitted to follow application of soluble phosphates may be named the following: rapid early growth both of roots and tops, increase in tillering in grains and grasses, earlier and therefore often more perfect ripening, increase of the availability of certain soil constituents, and larger acquisitions of atmospheric nitrogen.

1. *Rapid Early Growth of Both Roots and Tops.* — Many observers have noticed the quick start which plants from seed make when dissolved phosphates have been applied. Attention has been called to the differences in rate of development of the corn crop in the experiment comparing different phosphates.[1] In numerous other experiments which have been carried out here similar differences have been observed. Especially striking have been the results obtained with rape and cabbages both in field and pot experiments. Differences about as great have been noted in the case of soy beans and millet.

The fact that the differences in early root development are perhaps even more striking than in early top development has not been demonstrated in our experiments, but Hall,[2] points out that Sir John Lawes called attention to this effect more than sixty years ago. He refers to a water culture which demonstrates it, and suggests that this effect accounts for the extraordinary results often following even small applications of soluble phosphates. He states that an application of half a hundred weight per acre of superphosphate in Australia to soils not signally deficient in phosphoric acid often doubles the yield of cereals, and expresses his belief that the result is due to the stimulating action of the phosphoric acid upon the young roots. He points out that this action is particularly important in that semi-arid country because as a result the plant quickly gets its roots down into the cooler and moister subsoil upon which the yield of the crop largely depends.

This stimulation of early root development must be a very great benefit under the conditions of our agriculture and in our climate. The crop which early develops an extensive root system — both deep and broad — can much better resist our frequent drouths than one whose roots develop more tardily. It is apparent, also, since it is known that roots by direct and intimate contact with soil particles exercise an important influence in supplying the plant with food, that the more extensive the root development the more largely the plant will be able to utilize the resources of the soil itself.

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[1] See p. 154.

[2] "Fertilizers and Manures," p. 140.

The stimulation to rapid early development under discussion is especially important in the case of all crops with which it is for any reason unusually difficult to secure a perfect stand, whether from a habit of growth naturally slow and feeble at first, or from the fact that the seedlings are peculiarly subject to insect injury. The beet is an example of the first; the Swedish turnip of the second. In the cultivation of either table, sugar or mangel beets, and of all crops of the turnip or cabbage family, the use of soluble phosphates is highly important to enable them both to outgrow weeds and to withstand the attacks of flea beetles and aphids.

2. *Increase in Tillering of Cereal Grains.* — As cereal grains are quite unimportant in our agriculture no direct observations which demonstrate that the cereal grains tiller or "stool" more freely when soluble phosphates are applied have been made in our experiments. There seems, however, to be no doubt of the fact. Hall asserts it in the following words: "Both in the field and in pot experiments the phosphoric acid has a great effect in promoting the formation of adventitious buds, so leading to the tillering of the plant."[1] The beneficial effects of phosphates in top-dressing for hay are very likely associated in part with a similar effect, which should mean a closer turf and a thicker and heavier yield. The millets and Hungarian grass should, it would seem, show a similar influence.

3. *Earlier and More Perfect Ripening.* — The facts that in our experiments the more soluble phosphates have produced a larger proportion of sound and perfectly ripened corn and a larger proportion of well-ripened onions than the natural rock phosphates have been pointed out.[2] The more soluble phosphates in these experiments have also produced much the larger proportion of hard (mature) heads of cabbage. The fact that soluble phosphates in abundance favor perfect and relatively early maturity has been too often observed and is too well known to need demonstration.

With any crop, therefore, subject to possible frost injury in autumn, a free use of the more soluble and available phosphates should be the rule. In the case of garden crops, also, for which the price is usually much higher for the earliest product, the rule should be the same. A single day with such products as peas, sweet corn, tomatoes and many others which might be mentioned often means the difference between a large profit and a price which perhaps barely covers cost. The gardener, other things being equal, who uses soluble phosphates within reasonable limits most freely will be first in market with his product. No amount of previous use of natural rock phosphate can produce the same effect, for the phosphoric acid of these is not sufficiently soluble to exercise the required stimulation.

The superior color of fruits — especially of the apple — produced by trees in soils to which available phosphates have been freely applied is doubtless only a special illustration of this hastening effect on the ripening process. This effect on color has perhaps most frequently been attributed to the application of basic slag meal. It is, of course, understood that many other conditions also affect color.

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[1] "Manures and Fertilizers," p. 139.

[2] See pp. 154–155.

4. *Effect on the Availability of Soil Constituents.* — That the action of the soluble phosphates in the soil increases the availability of some of the important soil constituents seems to be generally held. This is a point which has not been made the subject of special investigation here. That it will make it possible for the plant to draw more largely upon the soil because of the increase in root development which it causes has been pointed out.[1] Aside from this it is believed that the soluble phosphates exert a direct chemical effect which results in bringing some of the soil constituents more largely into solution. All soluble phosphates contain calcium sulfate (land plaster), and this compound is held by many to be the constituent of acid phosphate most active in decomposing the complex silicates of the soil and rendering the potash they contain soluble and available to crops. Long-continued experiments in the use of land plaster, which have been connected with soil tests continued for twenty-six years have not given very material increases in crops which respond in marked degree to an application of muriate of potash alone. The average increase in 13 corn crops grown in this soil test during the twenty-six years, due to the annual application of muriate of potash at the rate of 160 pounds per acre, has been 27 bushels, while the average increase due to the annual application of plaster at the same rate has been 2½ bushels. It seems clear that had the plaster exercised a very important influence in making the potash of the soil (present in this case in very large amounts) available there must have been a larger increase in the corn crop following its use.

The use of superphosphate has been shown to be favorable to nitrification,[2] and must therefore increase the availability of the organic nitrogen-containing soil constituents.

It has been asserted that some of the constituents of acid phosphate act as catalytic agents in the soil, and by their action render soil constituents available; but that this is the case does not appear to have been fully established. On the whole, therefore, it seems to the writer that the direct chemical influence of soluble phosphates as affecting the availability of soil constituents is less important than the other secondary effects which have been considered.

5. *Larger Gain of Atmospheric Nitrogen.* — It has been demonstrated that the activity of bacteria which have the ability to fix atmospheric nitrogen in the soil is increased by the application of superphosphates, and that as a consequence more nitrogen is brought within reach of the crop and a larger yield usually obtained.[3]

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[1] See p. 161.

[2] Abst. E. S. R., Vol. XXVIII., p. 216: Patterson & Scott Jour. Dept. Agr. Victoria, 10 (1912).

[3] Abst. E. S. R., Vol. XX., p. 621: Löhnis & Pillai, Centbl. Bakt. 2 Abt. 20 (1908), No. 24–25.

CONCLUSIONS.

The principal points which have been presented that have a bearing upon the questions affecting the need and selection of phosphates will now be summarized. It is believed all are either well grounded in general knowledge and experience, supported by results of our own experiments reported in earlier pages, or established by the experiments of others.

1. The products chiefly sold from Massachusetts farms contain relatively little phosphoric acid; potash is contained in them in far larger proportion, usually from four to six times as much.

2. Most farmers use purchased stock or horse feeds rich in phosphoric acid, and thus greatly enrich the manure made in that compound.

3. Phosphoric acid is subject to much less waste from accumulating manures under usual conditions than potash.

4. The crops grown in our farm, garden and orchard practice all take from the soil far more potash than phosphoric acid.

5. The fertilizers in general use for the past fifty years have supplied far more phosphoric acid than potash.

6. Phosphoric acid is subject to extremely little loss from soils by leaching.

7. It seems clear from the preceding statements that under our system of agriculture our soils are not being depleted in phosphoric acid.

8. Chemical analysis of our leading soil types by conventional methods shows that the percentages of acid soluble phosphoric acid and potash are usually nearly equal; averages for the State, phosphoric acid, .214 per cent.; potash, .252.

9. If all of these compounds found in our average surface soil by conventional methods of analysis could be utilized —

The phosphoric acid would (according to crop) last from ninety-two to eight hundred years.

The potash would (according to crop) last from forty-two to two hundred and ninety years.

10. The total potash in the surface soil very materially exceeds the total phosphoric acid, and acid soluble potash is usually much more abundant in subsoils than phosphoric acid.

11. In spite of the relatively greater stock of total potash in soils than of total phosphoric acid, an application of the former in soluble forms in fertilizers has produced larger crop increases than has a similar application of phosphoric acid for the following: asparagus, potatoes, corn, hay, clover and soy beans. The only crops giving larger increases on phosphoric acid are crucifers (turnips, cabbages, etc.).

12. The results of hundreds of experiments at this station and in various parts of the State indicate that phosphoric acid is not the key to "permanent" (successful and profitable) "agriculture" in Massachusetts. It is not usually the element *in minimo.* Potash, as measured by crop requirements, is more often *in minimo,* and determines the yield.

13. The phosphoric acid capital in our soils is certainly not too large; doubtless it should in many cases be increased. Phosphates should be used in our agriculture, and the question whether the natural rock phosphates should be employed is an important one.

14. In experiments which have continued eighteen years, in which various fine-ground mineral phosphates, bone meals (raw, steamed and dissolved), slag meal, dissolved bone black and acid phosphate have been compared on the basis of equal annual liberal application of phosphoric acid, the results have been highly unfavorable to the natural mineral phosphates with all important crops.

15. The percentage increases (of all crops, 1899 to 1914, inclusive) show the following averages: —

	Per Cent.
Natural mineral phosphates,	9.13
Slag and bone meals,	42.24
"Dissolved" phosphates,	44.85

16. The "dissolved" phosphates are much more favorable to rapid early growth than the natural mineral phosphates.

17. The "dissolved" phosphates favor ripening, as shown by the smaller proportions of immature product, especially with corn, onions and cabbages.

18. The increases in crops produced by the slag, bone meals and "dissolved" phosphates exceed cost of the materials in much greater degree than is the case with the natural mineral phosphates. The average figures are, per acre: —

For natural mineral phosphates, annually,	$6 21
For slag and bone meals, annually,	36 23
For "dissolved" phosphates, annually,	34 57

19. The natural mineral phosphates gave yields after eighteen years' continuous use, yet more inferior as compared with the dissolved phosphates than in the earlier years. The increases for the corn crop are, per acre: —

	Bushels.	
	1899.	1914.
Natural mineral phosphates,	—2.41	—0.175
Slag and bone meals,	1.27	13.270
"Dissolved" phosphates,	5.03	15.370

20. It is clear that the natural agencies active in the soil in these experiments act upon the mineral phosphates with extreme slowness, in spite of the fact that large amounts of organic matter have been incorporated with it by the growth and turning under of green crops.

21. The fact that increases in crops, even on the dissolved phosphates, account for only a very small proportion of the total phosphoric acid applied — less than 10 pounds out of 216 per plot — indicates that the favorable effects were due chiefly to indirect causes.

22. The dissolved phosphates greatly stimulate early root and top development. This action is of great importance in enabling the crop to draw more largely upon the soil both for water and food, and in enabling some crops to resist insect injury.

23. Dissolved phosphates are reported to favor tillering (stooling), and this means a thicker growth of grains, grasses and millets.

24. Dissolved phosphates favor early and perfect ripening, and are therefore much to be preferred where earliness is desirable and in case of crops liable to autumn frost injury.

25. Dissolved phosphates, chiefly through the activity of the calcium sulfate which they contain may somewhat increase the availability of soil potash.

26. The use of dissolved phosphates has been shown to be favorable to nitrification, and to larger gain in atmospheric nitrogen acquired through the activity of soil bacteria.

27. Finally no injurious secondary effects are known to be associated with any reasonable use of dissolved phosphates. Our experiments indicate that they do not increase the necessity for the use of lime.

Massachusetts farmers, gardeners and orchardists are advised against the general use of raw rock phosphates. In so far as they are needed in our agriculture the phosphates employed should be the more soluble and available kinds, such as acid phosphate (dissolved rock), dissolved bone, basic slag meal and bone meals. The dissolved forms are advised for a quick start and early maturity. The mixed fertilizers upon our markets usually contain a large proportion of phosphoric acid chiefly in soluble and available forms. The station bulletins show their character. Those high-grade fertilizers with a large proportion of water-soluble phosphoric acid will be most favorable to a quick start and early maturity.

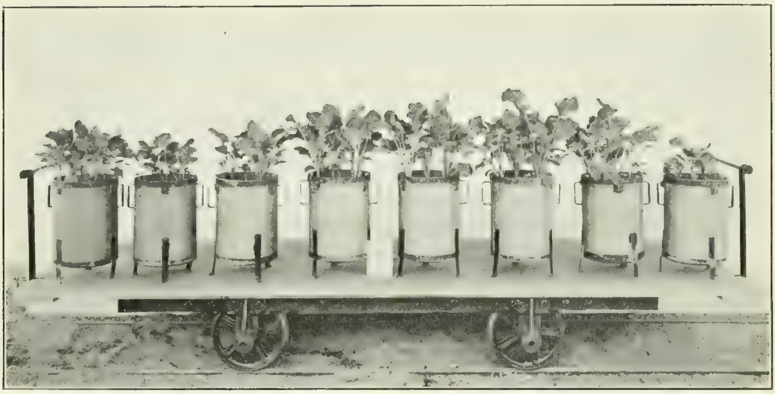
Natural rock phosphates are unadapted to the conditions of our agriculture, and their use will, with most of our crops and on most soils, give highly unsatisfactory results. What is needed in our agriculture is frequent (in case of many of our hoed crops, annual) applications of dissolved or quickly available phosphates.

Relative Phosphate Needs of Different Crops.

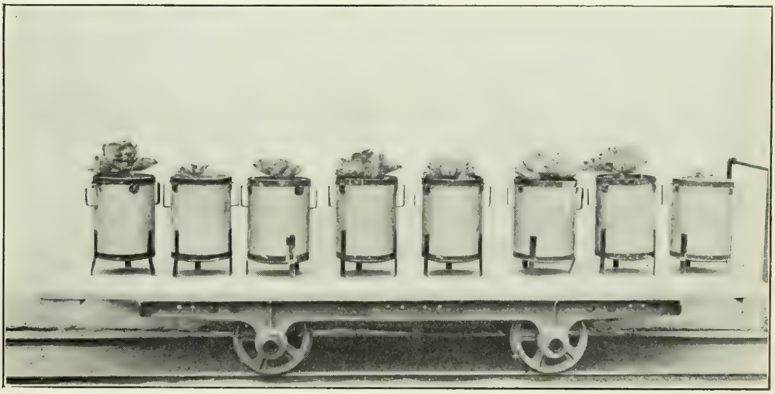
Our experiments indicate the use of phosphates to be especially necessary with all cruciferous crops (cabbage, turnip, cauliflower, Brussels sprouts, rape, etc.).

The onion also, especially if inclined to production of scallions, needs heavy applications of available phosphates.

For crucifers and onions in connection with materials supplying nitrogen and potash, 1,000 pounds per acre of a good acid phosphate, or an



Comparative test of phosphates, Dwarf Essex rape. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .44 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).



Comparative test of phosphates, cabbage. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .56 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).

equivalent of available phosphoric acid in a good mixed fertilizer, is usually desirable.

The yields of corn and potatoes seem to be in general less dependent upon applied phosphoric acid, but in the more soluble forms a fair amount is desirable, especially where early maturity is an object.

Grasses are affected relatively little by phosphates; clovers are somewhat more responsive, but in top-dressing mowings and pastures the proportion of phosphoric acid should be kept relatively low. Three hundred to 500 pounds per acre of acid phosphate in connection with potash and nitrogen materials, or an equivalent in a complete mixed fertilizer rich in nitrogen, will usually suffice in top-dressing mowings. Slag meal will be especially suitable where a large proportion of clovers is desirable, or in top-dressing soils which are moist and rich in organic matter. It seems also peculiarly adapted for use in connection with potash as a top-dressing for pastures, bringing in the more desirable grasses and white clover. The usual range in quantity needed appears to be between about 500 and 600 pounds per acre.

In orchard management phosphoric acid seems to favor both fruitfulness and good quality, and basic slag meal is in general favor among those who have tried it. This material in orchards, as in mowings and pastures, peculiarly favors clovers and other legumes, and thus indirectly reduces the necessity for nitrogen manuring. It does not, of course, materially affect the need for potash.

BULLETIN No. 163 AUGUST, 1915

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bacillary White Diarrhea (Bacterium Pullorum Infection) in Young Chicks in Massachusetts

By G. EDWARD GAGE and BERYL H. PAIGE
Department of Veterinary Science

This bulletin presents a brief history of the results of the study of Bacillary White Diarrhea by different investigators, and the discovery of a method of detecting, by means of an agglutination test of their blood, those hens in a flock carrying the infection. It shows that the disease is widely disseminated in Massachusetts, presents the complete records of the agglutination test of a number of breeding flocks, and urges the general adoption of the test as a means of eliminating the disease.

Requests for bulletins should be addressed to the
Agricultural Experiment Station,
Amherst, Mass.

Massachusetts Agricultural Experiment Station.

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[1] On leave.

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Approved by the State Board of Publication.

BACILLARY WHITE DIARRHEA (BACTERIUM PULLORUM INFECTION) IN YOUNG CHICKS IN MASSACHUSETTS.

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Purpose.

The object of this paper is to set forth the facts concerning bacillary white diarrhea of young chicks, together with a discussion concerning its cause, distribution, diagnosis and economic importance in the State of Massachusetts. It includes, also, the results obtained from the work of the Department of Veterinary Science in applying the macroscopic agglutination test as a means of detecting adult hens which may be the source of infection.

Brief History of Disease.

In 1900 Rettger[1] reported a peculiar ailment of hen-hatched chicks, and isolated from the liver and spleen an organism, pure cultures of which, when inoculated into healthy chicks, resulted in a reproduction of the disease; he was able to recover the organism from the internal organs of the dead chicks. In 1901 he[2] again reported a serious epidemic occurring on three adjoining farms and involving hundreds of chicks, all of which were hen-hatched. About 80 per cent. of the total flocks died, all exhibiting symptoms similar to those of the first epidemic. The organism was isolated, and inoculation experiments were again successful.

In 1908 Rettger and Harvey,[3] and in 1909 Rettger[4] alone, reported work carried on in connection with other epidemics showing that the organism was recovered and the disease successfully reproduced. They also described the details of attempts to transmit the disease. At this time the organism was designated *Bacterium pullorum.*

In 1909, after having carried on extensive co-operative experiments with Professor Stoneburn at the Storrs Agricultural Experiment Station,[5] it was found that the original source of the infection was the hen. Eggs from infected hens contain the organism in the yolks; chicks produced from infected eggs have the disease when hatched. The disease may be spread through the medium of infected food and water.

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[1] Rettger: "Fatal Septicemia in Young Chicks." New York Medical Journal, Vol. LXXI., 1900, p. 803.

[2] Rettger: "Fatal Septicemia in Young Chickens." New York Medical Journal, Vol. LXXIII., 1901, p. 267.

[3] Rettger and Harvey: "Fatal Septicemia in Young Chickens or White Diarrhea." Journal of Medical Research, Vol. XVIII., 1908, pp. 277-290.

[4] Rettger: "Further Studies on Fatal Septicemia in Young Chickens or White Diarrhea." Journal of Medical Research, Vol. XXI., 1909, pp. 115-123.

[5] Rettger and Stoneburn: "Bacillary White Diarrhea of Young Chicks," Bulletin No. 60, Storrs Agricultural Experiment Station.

In 1911 Gage[1] thoroughly investigated the matter of *Bacterium pullorum* infection and fully substantiated the work of Rettger and Stoneburn already cited, — that "white diarrhea," as poultrymen understand it, is a bacillary disease caused by *Bacterium pullorum*, and that the hen is the original source of infection, transmitting the organism from the ovary to the eggs. At that time the author, from the material received at the laboratory, concluded that most of the white diarrhea of chicks is bacillary white diarrhea, caused by the same organism isolated by Rettger and designated *Bacterium pullorum.*

Jones[2,3] also concluded that *Bacterium pullorum* produced fatal septicemia or bacillary white diarrhea in young chicks; and that they are most susceptible during the first twenty-four hours of life. *Bacterium pullorum* was found in the egg.

From the work of these investigators the conclusions are justifiable that *Bacterium pullorum* can produce a white diarrhea; the hen is the original source of infection; and that the disease may be transmitted from the ovary to eggs for hatching. The carrier problem thus is one of great importance. The question also arises as to how ovarian infection may be brought about. Experiments[4] were conducted for three years at the Storrs Experiment Station concerning this point, and one question which was answered positively by the results of this work and substantiated here in Massachusetts was, "Do chicks which survive an attack of bacillary white diarrhea become permanent carriers of the disease?" The results here at the Massachusetts Agricultural Experiment Station, and those from the experiment station at Storrs, are very decisive, and demonstrate that pullets infected as chicks may become permanent bacillus carriers. The three plates accompanying show graphically the cycle of infection, and picture normal and infected ovaries.

At this time it is important to state that in substantiation of the work of the Connecticut station on this point this department has been successful in several instances in isolating *Bacterium pullorum* from eggs laid by a Silver Penciled Wyandotte, the sole survivor of a large number of day-old chicks which were submitted to *Bacterium pullorum* infection.

Jones[5] suggested and used successfully an agglutination test for detect-

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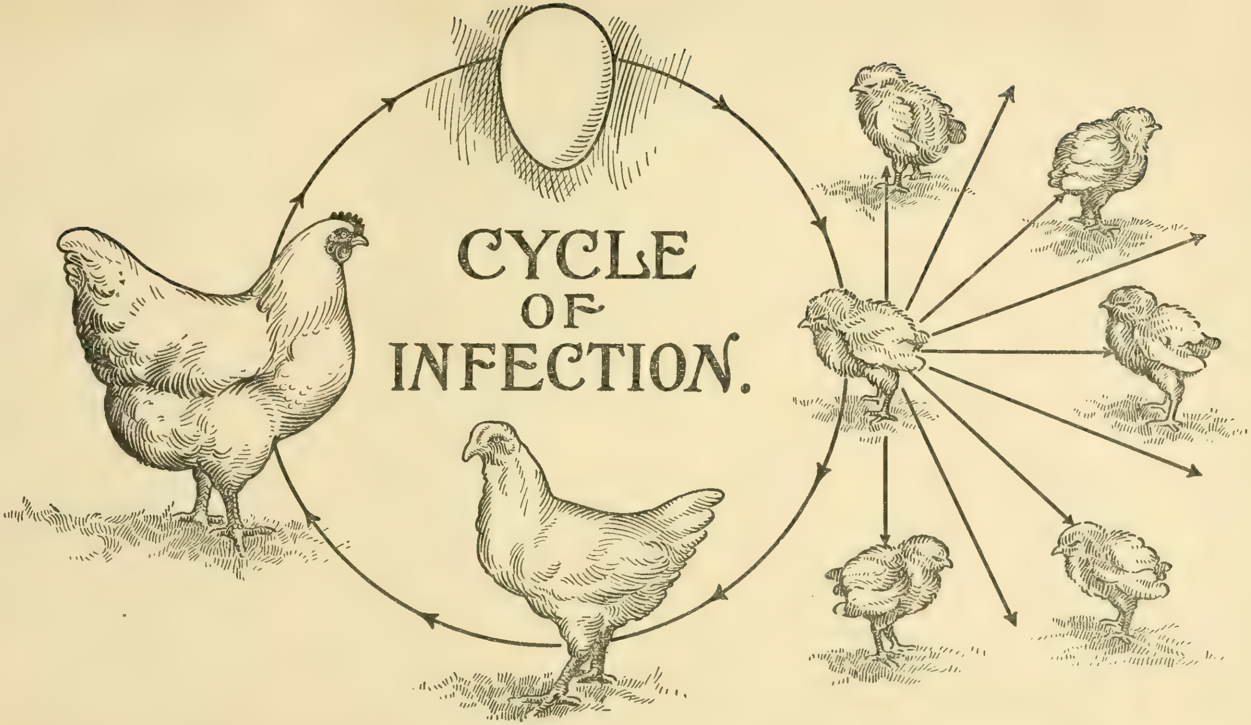
[1] Gage: "Notes on Ovarian Infection with *Bacterium pullorum* (Rettger) in the Domestic Fowl." Journal of Medical Research, Vol. XXIV., No. 3 (New Series, Vol. XIX., No. 3), pp. 491-496, June, 1911.

[2] Jones: "Annual Report of the New York State Veterinary College," Ithaca, N. Y., 1910, p. 111.

[3] Jones: "Annual Report of the New York State Veterinary College," Ithaca, N. Y., 1910-11, p. 69.

[4] Rettger, Kirkpatrick and Jones, R. E.: Bulletin No. 77, Storrs Agricultural Experiment Station.

[5] Jones, F. S.: Journal of Medical Research, Vol. XXVII., No. 4 (New Series, Vol. XXII., No. 4), pp. 481-495, March, 1913.



Reproduced from diagram (from Bulletin No. 68) showing how bacillary white diarrhea perpetuates itself in the breeding stock. (By courtesy of the Storrs Agricultural Experiment Station, Storrs, Conn.

ing this infection. Gage [1] and Rettger [2] have also used and applied it with good results, both in diagnosing the infection and as a basis for control and eradicating the infection from breeding flocks.

ESTABLISHMENT OF METHODS FOR DETECTING CARRIERS OF THE DISEASE.

Since it has been shown conclusively by the workers quoted above that infected ovaries constitute the real source of infection in bacillary white diarrhea of chicks, the basis of prevention rests to a great extent upon this significant fact. Then, too, the work already cited has exhibited the scientific proof which shows that chicks surviving an attack of bacillary white diarrhea may become permanent carriers.

Attempts have been made to apply various tests for locating this infection in adult hens, but the macroscopic agglutination test, as noted above, which is discussed later in this paper, has proven reliable and practical for testing the blood of mature stock. The results reported in Bulletin No. 148 of this station, together with those reported from Cornell and Connecticut, demonstrate that the value of the macroscopic agglutination test can no longer be doubted. It furnishes a practical method of diagnosing infection in adult hens. It is inexpensive and reliable, and up to the present time nothing has occurred to detract from the merits of the test. In the hands of properly qualified persons, and carried out under observation of the laws of pathology, both from the standpoint of the study of disease and eradication of disease, as indicated by our records to date, it is fast proving to be more and more valuable as a means of detecting birds which may be a source of infection to young day-old chicks.

Therefore, with this consideration, nothing should stand in the way for proper authorities to make it possible for the present workers in this field to continue this important work and apply the test extensively throughout Massachusetts, and aid in ridding breeding flocks throughout the State of these permanent carriers of *Bacterium pullorum*. Backed by our present data from the laboratory, this work could be carried on with every promise of success.

INFECTION IN MASSACHUSETTS.

The establishment of such important facts in regard to bacillary white diarrhea as its cause, original source, and mode of transmission, and the perfection of a test which is able to detect the sources of the disease, are subjects which have been referred to in an earlier part of this paper. The question which confronts the poultryman of Massachusetts is, "Does bacillary white diarrhea exist to any extent in Massachusetts?" In reply to this question we set forth the data that we have obtained up to date, as well as the methods used in procuring them.

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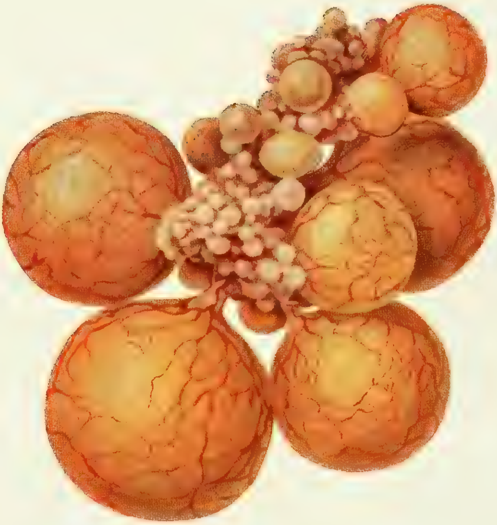
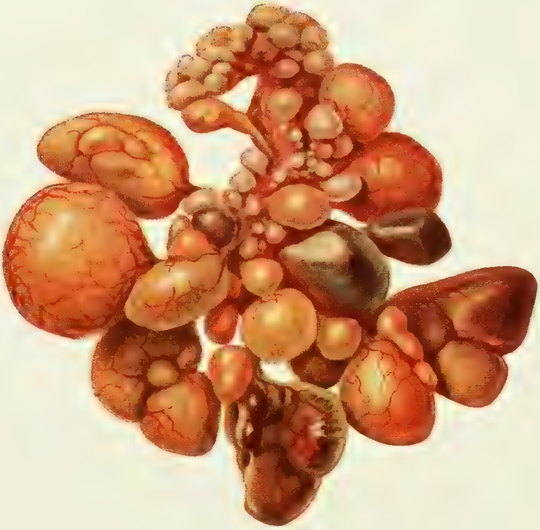
[1] Gage: "On the Diagnosis of Infection with *Bacterium pullorum* in the Domestic Fowl." Massachusetts Agricultural Experiment Station, Bulletin No. 148, April, 1914.

[2] Rettger: Storrs Agricultural Experiment Station, Bulletin No. 77, June, 1914, p. 272.



NORMAL OVARY

Reproduced from Storrs Agricultural Experiment Station, Bulletin 77, Storrs, Conn.



INFECTED OVARY (*B. pullorum*)

Reproduced from Storrs Agricultural Experiment Station, Bulletin 77, Storrs, Conn.

METHODS USED IN LOCATING AND ERADICATING INFECTION.

As the presence of *Bacterium pullorum* infection in a flock is strikingly indicated by the death of a large number of young chicks, it is to be expected that the location of the disease can be readily determined by the examination of chicks which have died. It is by this means that we have obtained data in regard to most of the infected areas in the State. In two cases, however, the flock owners, believing from their chick losses that bacillary white diarrhea existed in their flocks, asked to have their adult birds tested without sending chicks for preliminary examination. Results of the agglutination tests gave proof that the disease was present in these flocks.

METHODS USED IN EXAMINATION OF CHICKS.

In examining dead chicks which have been received in the laboratory the following procedure is employed: The general appearance of chicks when they are received is noted. Each chick is numbered and that number recorded, so that individual records are kept on the examination of each bird. They are then pinned, by wings and feet, ventral side upward, to a sterile dissecting board, the feathers are removed by singeing with a gas flame, and the abdominal and thoracic organs exposed by cutting through the walls of these cavities. At this time any internal pathological features — *i.e.*, the color of liver, size, consistency and color of the unabsorbed yolk (if present), appearance of the ceca, etc. — are noted. Employing the usual methods to prevent outside contamination, tubes of sterile agar-agar are inoculated with material from such organs as the heart, liver, unabsorbed yolk and intestinal tract, and the tubes are allowed to stand in the incubator at 38° C. until sufficient time has elapsed to insure the growth of *Bacterium pullorum,* if present. Material in all tubes is then carefully examined for this organism and the findings recorded. When *Bacterium pullorum* is found, a culture of it is retained in the laboratory under an individual retention number, and thus may be used for future reference.

Since February of this year our records show that between 700 and 800 chicks, the majority of them dead, have been received for examination. In some cases, however, live ones have come for observation, and these have been placed under favorable conditions and given the food best suited to their ages. Any that died have been examined according to the method given above.

SUMMARY OF DATA SECURED BY CHICK AUTOPSIES.

To summarize briefly the areas in the State in which the above method has shown that infection exists we refer to Map I. As we mentioned before, all localities showing infection, with the exception of two flocks in which the presence of the disease was detected by the agglutination test, have been determined by the examination of dead chicks.

THE AGGLUTINATION TEST.

While the macroscopic agglutination test is of service in the location of bacillary white diarrhea infection, its greatest importance lies in the part it plays in the eradication of this disease by detecting in a breeding flock adult birds which are acting as carriers of the organism *Bacterium pullorum*.

In spite of the fact that a detailed account of this test for the detection of adult birds which are harboring or have harbored *Bacterium pullorum* infection has been presented in an earlier bulletin (Gage, Geo. Edward: Bulletin No. 148, 1914, Massachusetts Agricultural Experiment Station. "On the Diagnosis of Infection with *Bacterium pullorum* in the Domestic Fowl"), we wish to review briefly the important points of the method, especially in relation to the work carried on during the last few months.

As the reader of our earlier bulletin will remember, the two important biological factors necessary for making the macroscopic agglutination test are (1) a test fluid containing a suspension of the organism causing the disease *Bacterium pullorum*, and (2) a sample of blood serum from the individual to be tested, and the test is based on the fact that the blood sera of infected and non-infected birds when mixed with the test fluid react differently. The serum of the former, because of the presence of an agglutinin, a substance formed in the body of the bird because of infection with *Bacterium pullorum*, is capable of producing, when brought in contact with a suspension of the organism, a clumping together of the bacteria, a phenomenon which blood from non-infected birds does not show.

TEST FLUID.

As earlier experiments have shown that a polyvalent test fluid is better suited for laboratory routine than a monovalent one (Bulletin No. 148, pp. 15, 16), we selected for our work the following strains of *Bacterium pullorum:* —

Strain 1. — Isolated March, 1914, from chick received from central Massachusetts.

Strain 2. — Isolated summer of 1913 from chick inoculated experimentally with *Bacterium pullorum* isolated from egg from eastern Massachusetts.

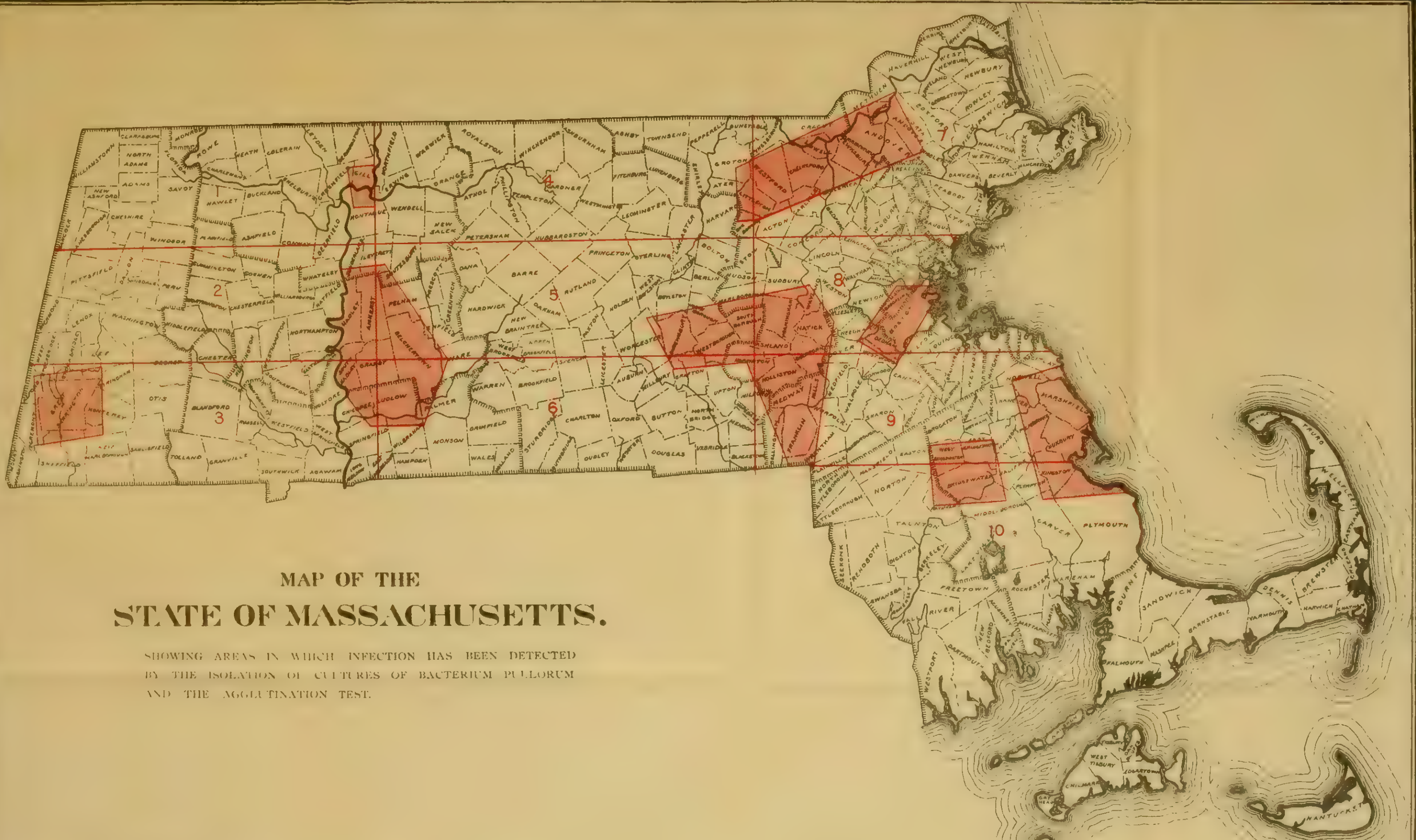
Strain 4. — Isolated from chick from eastern Massachusetts.

Strain 5. — Original strain of *Bacterium pullorum*, isolated 1911 from chick in Maryland.

Strain 6. — Isolated spring of 1914 from Massachusetts material sent to laboratory.

These gave us representative cultures from several localities, and all test fluids have been mixtures of four or all these strains.

These cultures were studied to make sure of their purity, grown in large quantities on agar-agar at a temperature of 38° C., and the growth washed off in a carbolated sodium chloride solution (0.85 per cent. NaCl solution,



MAP OF THE

STATE OF MASSACHUSETTS.

SHOWING AREAS IN WHICH INFECTION HAS BEEN DETECTED BY THE ISOLATION OF CULTURES OF BACTERIUM PULLORUM AND THE AGGLUTINATION TEST.

B. Courtesy of State Department of Health.

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1 per cent. glycerine, 0.5 per cent. phenol). The resulting cloudy fluid was then well shaken, filtered through cotton, tested and preserved on ice. In case any bottle of test fluid was not used immediately it was retested before using it for diagnostic purposes.

Methods of drawing and treating Blood Samples.

In drawing blood samples from the birds tested we have found it convenient to make use of some sort of improvised table upon which the birds can be laid; and, at the same time, small collecting tubes, absorbent cotton and carbolic acid can be arranged within easy reach.

The hen is laid on her back on the table, with one wing projecting over the edge; the feathers are quickly removed from a small area on the underside of the wing, so that the course of the wing vein may be seen clearly, and the region washed with absorbent cotton wet with 2.5 per cent. carbolic acid. With scissors, or a sharp knife, a cut is then made in the vein near the outer bend of the wing, which is slanted in such a way that the blood flows directly into small sterile tubes. After a small amount (2 to 3 cubic centimeters) has been collected the cut is washed again with carbolic acid, and fresh, dry absorbent cotton is pressed against the wound to check the flow of blood. With the cotton still under the wing the bird is placed gently on the floor of the pen, and, in most cases, there is no trouble with further bleeding. In the few instances where the blood has not ceased flowing immediately additional pieces of absorbent cotton, pressed over the incision and left under the wing, have been sufficient to stop bleeding. The tube in which the blood has been collected is then plainly marked with the number of the hen from which it came, tightly corked and set away to clot.

After all samples are collected from the flock the tubes of blood are taken to the laboratory and set on the ice until the clots are well formed. They are then removed from the sides of the tubes and broken up by means of sterile brass strips, one of which is in each collecting tube. After removing the brass strips it is customary to place the samples again on ice over night. By morning the serum appears in appreciable quantities above the clot, and, after centrifugalizing the contents of each tube, it may be easily pipetted from the collecting tube into a sterile bottle in which it is diluted 1–20 with sterile 0.85 per cent. salt solution, and kept on ice until needed for further work.

Making the Agglutination Test.

For these tests small test tubes 100 millimeters long and 10 millimeters caliber have been employed. In the majority of cases three tubes have been used for each individual tested, two of the tubes containing 1.5 cubic centimeters test fluid and the third, 1.5 cubic centimeters carbolated salt solution for a control. In tube No. 1 has been placed 0.3 cubic centimeters diluted blood serum, making a final dilution of serum, 1–100;

in tube No. 2, 0.15 cubic centimeters serum (final dilution 1–200), and in tube No. 3, 0.3 cubic centimeters diluted serum. In some cases a third tube of test fluid has been used with a 1–500 dilution of serum. All tubes have been labelled with hen numbers, dilution of serum contained, and shaken to afford thorough mixing of the test fluid and serum. In each set of tests one tube containing test fluid alone has been placed as a second means of controlling the results. At this point the tubes have been set in the incubator at 38° C., and readings have been made at the end of twenty-four, forty-eight and seventy-two hours.

In tests made on infected flocks readings of the tubes showed that in some containing test fluid and serum, fine, flakelike masses had settled to the bottom and sides, leaving the supernatant fluid clear. In other tubes the mixture of test fluid and serum remained hazy as it was at the time tests were set up, and no flaky sediment appeared. In the first case it is evident that the serum contained an agglutinin which had caused the agglutination of the bacteria of the test fluid, and all birds with sera reacting in such a way have been reported as positive reactors.

For all flocks tested record cards of all details have been filed, the material including, in addition to records of hen numbers and all readings of tubes, such data as date of drawing of blood samples, date same have been received in laboratory, their condition, and notes on the test fluid. From these records, at the conclusion of the tests, a complete report can be sent to the owner of the flock. In these reports a list of the numbers of all hens tested has been sent, the numbers of positive reactors being preceded by a red star. Together with this list has been sent a recommendation to be followed in the eradication of infection from the flock. In addition to the above data the laboratory record cards include data received from the owner concerning the results he has attained from tested stock.

Data secured from Agglutination Tests.

In organizing for publication the data gained up to the present time from our work with the agglutination test it has seemed wise to divide a map of the State of Massachusetts into districts, and, using these districts as units, to make a chart showing the results of the agglutination tests on representative flocks in these areas.

This chart gives the number of the district from which the flock has been chosen, — this number corresponding to number of district on map, — the laboratory number of each bird, owner's number of bird, results of the tests in dilutions 1–100 and 1–200 (— indicates a negative, + a positive reaction), total numbers of individuals tested in flock, number reacting positively, and percentage of positive reactors. In this way it will be possible for poultrymen in the various districts to get complete data from representative flocks.

Chart showing Results of Agglutination Tests for Bacterium Pullorum Infection in Blood of Breeding Flocks. These are Representative Flocks chosen from Districts of Massachusetts.

District 1.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
3- 1	2	–	–			
3- 2	3	+	+			
3- 3	8	+	+			
3- 4	10	+	+			
3- 5	12	–	–			
3- 6	13	+	+			
3- 7	*13	+	+			
3- 8	15	+	+			
3- 9	16	–	–			
3- 10	*16	–	–			
3- 11	17	–	–			
3- 12	18	–	–			
3- 13	21	–	–			
3- 14	22	+	+			
3- 15	23	–	–			
3- 16	24	–	–			
3- 17	25	–	–			
3- 18	27	+	+			
3- 19	28	–	–			
3- 20	29	+	+			
3- 21	30	+	+			
3- 22	31	+	–			
3- 23	35	+	+			
3- 24	37	–	–			
3- 25	38	+	+			
3- 26	39	+	+			
3- 27	42	+	+			
3- 28	43	–	–			
3- 29	44	+	+			
3- 30	45	+	+			
3- 31	*45	+	+			
3- 32	46	+	+			
3- 33	47	+	+			
3- 34	49	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 1 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1–100.	Dilution 1–200.			
3- 35	50	+	+			
3- 36	51	−	−			
3- 37	52	+	+			
3- 38	53	+	+			
3- 39	54	+	+			
3- 40	57	+	+			
3- 41	58	−	−			
3- 42	61	+	+			
3- 43	62	+	+			
3- 44	65	−	−			
3- 45	67	+	+			
3- 46	69	+	+			
3- 47	70	+	+			
3- 48	71	−	−			
3- 49	72	−	−			
3- 50	74	−	−			
3- 51	75	−	−			
3- 52	76	−	−			
3- 53	77	+	+			
3- 54	79	+	+			
3- 55	80	+	+			
3- 56	82	+	+			
3- 57	84	+	+			
3- 58	85	+	+			
3- 59	86	+	+			
3- 60	87	−	−			
3- 61	89	−	−			
3- 62	91	−	−			
3- 63	92	+	+			
3- 64	93	−	−			
3- 65	94	+	+			
3- 66	97	−	−			
3- 67	100	+	−			
3- 68	101	+	+			
3- 69	102	−	−			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 1 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
3- 70	103	–	–			
3- 71	104	+	+			
3- 72	106	+	+			
3- 73	115	+	+			
3- 74	118	–	–			
3- 75	124	–	–			
3- 76	125	–	–			
3- 77	*125	–	–			
3- 78	128	–	–			
3- 79	129	–	–			
3- 80	131	–	–			
3- 81	132	–	–			
3- 82	133	–	–			
3- 83	134	+	+			
3- 84	135	–	–			
3- 85	136	–	–			
3- 86	137	–	–			
3- 87	138	–	–			
3- 88	140	–	–			
3- 89	141	–	–			
3- 90	142	+	+			
3- 91	143	–	–			
3- 92	144	–	–			
3- 93	146	–	–			
3- 94	147	+	+			
3- 95	148	+	+			
3- 96	149	–	–			
3- 97	*149	–	–			
3- 98	150	+	+			
3- 99	151	+	+			
3-100	152	–	–			
3-101	153	+	–			
3-102	154	–	–			
3-103	155	+	–			
3-104	156	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 1 — Continued.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
3-105	157	−	−			
3-106	159	−	−			
3-107	160	−	−			
3-108	161	−	−			
3-109	162	+	+			
3-110	163	+	+			
3-111	164	−	−			
3-112	165	+	+			
3-113	167	−	−			
3-114	168	−	−			
3-115	169	+	+			
3-116	170	−	−			
3-117	171	−	−			
3-118	172	−	−			
3-119	174	+	−			
3-120	175	+	−			
3-121	176	−	−			
3-122	177	−	−			
3-123	178	−	−			
3-124	179	+	+			
3-125	180	−	−			
3-126	182	+	+			
3-127	183	−	−			
3-128	184	−	−			
3-129	186	−	−			
3-130	187	+	+			
3-131	188	+	+			
3-132	189	+	+			
3-133	191	−	−			
3-134	192	−	−			
3-135	193	+	+			
3-136	194	+	−			
3-137	195	−	−			
3-138	196	+	+			
3-139	197	+	+			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 1 — Continued.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
3-140	198	+	+			
3-141	*198	−	−			
3-142	199	+	+			
3-143	200	+	−			
3-144	*200	+	+			
3-145	202	+	+			
3-146	203	−	−			
3-147	205	−	−			
3-148	206	−	−			
3-149	208	+	+			
3-150	209	+	+			
3-151	210	−	−			
3-152	213	−	−			
3-153	214	−	−			
3-154	218	+	+			
3-155	219	+	−			
3-156	220	+	+			
3-157	*220	+	+			
3-158	221	+	+			
3-159	223	−	−			
3-160	224	−	−			
3-161	231	−	−			
3-162	250	−	−			
3-163	277	+	+			
3-164	283	+	+			
3-165	306	+	+			
3-166	321	+	+			
3-167	326	+	+			
3-168	336	+	+			
3-169	346	+	+			
3-170	355	−	−			
3-171	359	−	−			
3-172	419	+	+			
3-173	436	+	+			
3-174	443	+	+			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 1 — Concluded.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
3-175	445					
3-176	453	+	+			
3-177	457	−	−			
3-178	459	−	−			
3-179	466	−	−			
3-180	481	+	+			
3-181	487	+	+			
3-182	488	−	−			
3-183	494	+	+			
3-184	498	+	−			
3-185	517	+	+			
3-186	537	+	+			
3-187	550	−	−			
3-188	570	+	+			
3-189	575	+	+			
3-190	594	+	+			
3-191	Male 6	−	−			
3-192	Male 19	−	−			
3-193	Male 55					
3-194	Male 57	−	−			
3-195	Male 112	−	−			
3-196	Male 113	−	−			
3-197	Male 139	−	−			
3-198	Male 166	−	−			
3-199	Male 201	−	−			
3-200	Male 235	−	−			
3-201	Male 289					
3-202	Male 295	+	+			
3-203	Male 499	−	−	203[1]	100	50.0

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[1] Of 203 samples drawn, 3 were received in condition not suitable for further work.

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1–100.	Dilution 1–200.			
2– 1	13	–	–			
2– 2	16	+	–			
2– 3	19	–	–			
2– 4	45	–	–			
2– 5	49	–	–			
2– 6	67	–	–			
2– 7	119	–	–			
2– 8	122	–	–			
2– 9	129	–	–			
2– 10	*129	–	–			
2– 11	130	–	–			
2– 12	133	–	–			
2– 13	136	–	–			
2– 14	139	–	–			
2– 15	174	–	–			
2– 16	209	–	–			
2– 17	210	–	–			
2– 18	245	–	–			
2– 19	268	–	–			
2– 20	284	–	–			
2– 21	288	+	–			
2– 22	294	–	–			
2– 23	302	–	–			
2– 24	303	–	–			
2– 25	304	–	–			
2– 26	305	–	–			
2– 27	312	–	–			
2– 28	330	–	–			
2– 29	393	–	–			
2– 30	395	–	–			
2– 31	400	–	–			
2– 32	411	–	–			
2– 33	413	+	+			
2– 34	415	+	+			

Chart showing Results af Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
2- 35	446	–	–			
2- 36	447	–	–			
2- 37	448	–	–			
2- 38	449	–	–			
2- 39	462	–	–			
2- 40	506	–	–			
2- 41	558	–	–			
2- 42	611	–	–			
2- 43	640	–	–			
2- 44	655	–	–			
2- 45	664	–	–			
2- 46	714	–	–			
2- 47	728	–	–			
2- 48	732	–	–			
2- 49	753	–	–			
2- 50	759	+	+			
2- 51	762	+	+			
2- 52	763	–	–			
2- 53	784	–	–			
2- 54	813	–	–			
2- 55	892	–	–			
2- 56	1015	–	–			
2- 57	1016	–	–			
2- 58	1043	–	–			
2- 59	1055	–	–			
2- 60	1068	+	–			
2- 61	1412	+	+			
2- 62	1444	–	–			
2- 63	2311	–	–			
2- 64	2324	–	–			
2- 65	2340	–	–			
2- 66	2344	+	+			
2- 67	2352	–	–			
2- 68	2379	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
2- 69	2405	+	−			
2- 70	2427	−	−			
2- 71	2437	+	−			
2- 72	2443	−	−			
2- 73	2453	−	−			
2- 74	2454	−	−			
2- 75	2455	−	−			
2- 76	2469	−	−			
2- 77	2471	+	−			
2- 78	2478	−	−			
2- 79	2479	−	−			
2- 80	2481	−	−			
2- 81	2484	−	−			
2- 82	2485	−	−			
2- 83	2494	−	−			
2- 84	2522	−	−			
2- 85	2532	−	−			
2- 86	2540	−	−			
2- 87	2541	−	−			
2- 88	2547	−	−			
2- 89	2551	−	−			
2- 90	2552	−	−			
2- 91	2555	−	−			
2- 92	2558	−	−			
2- 93	2559	−	−			
2- 94	2560	+	−			
2- 95	2564	−	−			
2- 96	2565	−	−			
2- 97	2567	−	−			
2- 98	2591	−	−			
2- 99	2637	+	−			
2-100	2638	−	−			
2-101	2670	+	−			
2-102	2675	+	+			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
2-103	2683	–	–			
2-104	2691	–	–			
2-105	2693	–	–			
2-106	2701	–	–			
2-107	2703	–	–			
2-108	2742	–	–			
2-109	2746	–	–			
2-110	2787	–	–			
2-111	2790	–	–			
2-112	2794	–	–			
2-113	2834	–	–			
2-114	2839	–	–			
2-115	2840	–	–			
2-116	2841	–	–			
2-117	2855	–	–			
2-118	2858	–	–			
2-119	2859	–	–			
2-120	2861	–	–			
2-121	2863	–	–			
2-122	2878	+	–			
2-123	3006	+	–			
2-124	3116	+	–			
2-125	3030	–	–			
2-126	3080	–	–			
2-127	3081	–	–			
2-128	3083	–	–			
2-129	3088	–	–			
2-130	3131	–	–			
2-131	3151	–	–			
2-132	3163	–	–			
2-133	3172	–	–			
2-134	3177	–	–			
2-135	3179	–	–			
2-136	3180	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test. Dilution 1-100.	Agglutination Test. Dilution 1-200.	Total Number in Flock.	Total Number infected.	Per Cent. infected.
2-137	3182	–	–			
2-138	3208	–	–			
2-139	3256	–	–			
2-140	3257	+	+			
2-141	3258	+	+			
2-142	3324	–	–			
2-143	3336	–	–			
2-144	3337	+	+			
2-145	3357	–	–			
2-146	3358	–	–			
2-147	3365	–	–			
2-148	3366	–	–			
2-149	3377	–	–			
2-150	3394	–	–			
2-151	3411	–	–			
2-152	3413	–	–			
2-153	3415	–	–			
2-154	3489	–	–			
2-155	3491	–	–			
2-156	3492	–	–			
2-157	3504	+	+			
2-158	3507	–	–			
2-159	3521	–	–			
2-160	3524	–	–			
2-161	3532	–	–			
2-162	3546	–	–			
2-163	3557	+	–			
2-164	3565	–	–			
2-165	3567	–	–			
2-166	3571	–	–			
2-167	3578	–	–			
2-168	3588	–	–			
2-169	3589	–	–			
2-170	3600	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
2-171	3601	–	–			
2-172	3625	–	–			
2-173	3627	–	–			
2-174	3634	–	–			
2-175	3639	–	–			
2-176	3640	–	–			
2-177	3659	–	–			
2-178	3693	–	–			
2-179	3694	–	–			
2-180	3719	–	–			
2-181	3919	+	+			
2-182	4002	+	+			
2-183	4007	–	–			
2-184	4012	–	–			
2-185	4017	–	–			
2-186	4018	–	–			
2-187	4021	–	–			
2-188	4022	–	–			
2-189	4024	–	–			
2-190	4027	–	–			
2-191	4030	–	–			
2-192	4039	–	–			
2-193	4041	–	–			
2-194	4042	–	–			
2-195	4043	–	–			
2-196	4045	–	–			
2-197	4046	–	–			
2-198	4054	–	–			
2-199	4055	–	–			
2-200	4058	–	–			
2-201	4068	–	–			
2-202	4070	–	–			
2-203	4071	–	–			
2-204	4072	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1–100.	Dilution 1–200.			
2–205	4076	–	–			
2–206	4086	–	–			
2–207	4087	–	–			
2–208	4090	+	+			
2–209	4091	–	–			
2–210	4095	–	–			
2–211	4097	–	–			
2–212	4099	–	–			
2–213	4100	–	–			
2–214	4101	–	–			
2–215	4103	–	–			
2–216	4107	–	–			
2–217	4109	–	–			
2–218	4113	+	+			
2–219	4116	–	–			
2–220	4119	–	–			
2–221	4120	–	–			
2–222	4121	–	–			
2–223	4124	–	–			
2–224	4125	–	–			
2–225	4126	–	–			
2–226	4127	–	–			
2–227	4130	–	–			
2–228	4131	–	–			
2–229	4132	–	–			
2–230	4135	–	–			
2–231	4136	–	–			
2–232	4138	–	–			
2–233	4139	–	–			
2–234	4140	–	–			
2–235	4141	–	–			
2–236	4145	–	–			
2–237	4146	–	–			
2–238	4149	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected
		Dilution 1-100.	Dilution 1-200.			
2-239	4151	−	−			
2-240	4155	−	−			
2-241	4156	−	−			
2-242	4173	−	−			
2-243	4178	−	−			
2-244	4181	−	−			
2-245	4182	−	−			
2-246	4183	−	−			
2-247	4184	−	−			
2-248	4186	+	+			
2-249	4251	−	−			
2-250	4252	−	−			
2-251	4254	−	−			
2-252	4255	−	−			
2-253	4256	−	−			
2-254	4257	−	−			
2-255	4259	−	−			
2-256	4261	−	−			
2-257	4262	−	−			
2-258	4263	−	−			
2-259	4266	−	−			
2-260	4267	−	−			
2-261	4268	−	−			
2-262	4269	−	−			
2-263	4270	−	−			
2-264	4272	−	−			
2-265	4273	−	−			
2-266	4274	−	−			
2-267	4275	−	−			
2-268	4621	+	+			
2-269	4666	−	−			
2-270	4667	−	−			
2-271	4694	−	−			
2-272	4695	−	−			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
2-273	4724	–	–			
2-274	4753	–	–			
2-275	7256	–	–			
2-276	7257	–	–			
2-277	7258	–	–			
2-278	7259	–	–			
2-279	7261	–	–			
2-280	7262	–	–			
2-281	7263	–	–			
2-282	7264	–	–			
2-283	72600	–	–			
2-284	0407	+	+			
2-285	A0401T	–	–			
2-286	A0402T	–	–			
2-287	A0403T	–	–			
2-288	A0404T	–	–			
2-289	A0405T	–	–			
2-290	A0406T	–	–			
2-291	A0410T	–	–			
2-292	A0412T	–	–			
2-293	A0414T	–	–			
2-294	A0416T	–	–			
2-295	A0417T	–	–			
2-296	A0418T	–	–			
2-297	A0419T	–	–			
2-298	A0420T	–	–			
2-299	A0421T	–	–			
2-300	A0422T	+	–			
2-301	A0423T	–	–			
2-302	A254	–	–			
2-303	A255	–	–			
2-304	A258	–	–			
2-305	A269	–	–			
2-306	A279	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Continued.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
2-307	A296	+	+			
2-308	A297	−	−			
2-309	A302	−	−			
2-310	A304	−	−			
2-311	A323	−	−			
2-312	A325	−	−			
2-313	A330	−	−			
2-314	A332	−	−			
2-315	A350	−	−			
2-316	A355	−	−			
2-317	A360	−	−			
2-318	A372	−	−			
2-319	A374	−	−			
2-320	A379	−	−			
2-321	A382	−	−			
2-322	A394	−	−			
2-323	C13	−	−			
2-324	C19	−	−			
2-325	C53	+	−			
2-326	C70970	−	−			
2-327	C70990	−	−			
2-328	C72510	−	−			
2-329	C72520	−	−			
2-330	C72530	−	−			
2-331	C72540	−	−			
2-332	C72550	−	−			
2-333	C72770	−	−			
2-334	C72780	−	−			
2-335	C72790	−	−			
2-336	C72800	−	−			
2-337	Conn311	−	−			
2-338	Conn314	−	−			
2-339	Conn320	−	−			
2-340	1R	+	−			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 2 — Concluded.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
2-341	2R	–	–			
2-342	3R	–	–			
2-343	4R	–	–			
2-344	5R	–	–			
2-345	6R	–	–			
2-346	7R	–	–			
2-347	8R	–	–			
2-348	9R	–	–			
2-349	10R	–	–			
2-350	11R	–	–			
2-351	12R	–	–			
2-352	13R	–	–			
2-353	14R	–	–			
2-354	15R	+	+			
2-355	16R	–	–			
2-356	21R	–	–			
2-357	17L	–	–			
2-358	18L	–	–			
2-359	19L	–	–			
2-360	20L	–	–			
2-361	4172	–	–			
2-362	4185	–	–			
2-363	4195	–	–			
2-364	4196	–	–			
2-365	4197	–	–			
2-366	4198	–	–			
2-367	4199	–	–	367	36	9.8

District 3.

Laboratory Number.	Hen Number.	Dilution 1-100.	Dilution 1-200.	Total Number in Flock.	Total Number infected.	Per Cent. infected.
8- 1	1	–	–			
8- 2	3	–	–			
8- 3	4	–	–			
8- 4	6	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 3 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
8- 5	7	–	–			
8- 6	8	–	–			
8- 7	11	–	–			
8- 8	13	–	–			
8- 9	15	–	–			
8-10	17	–	–			
8-11	18	–	–			
8-12	19	–	–			
8-13	21	–	–			
8-14	25	–	–			
8-15	27	–	–			
8-16	33	–	–			
8-17	35	–	–			
8-18	36	–	–			
8-19	37	–	–			
8-20	38	–	–			
8-21	39	–	–			
8-22	*39	–	–			
8-23	40	–	–			
8-24	42	–	–			
8-25	51	–	–			
8-26	52	–	–			
8-27	54	–	–			
8-28	87	–	–			
8-29	91	–	–			
8-30	96	–	–	30	0	0.0
9- 1	2	+	+			
9- 2	17Y	–	–			
9- 3	18	–	–			
9- 4	21	–	–			
9- 5	24	–	–			
9- 6	29	–	–			
9- 7	37	+	+			
9- 8	40	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 3 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
9- 9	44	–	–			
9-10	53Y	+	+			
9-11	61	–	–			
9-12	65	–	–			
9-13	66	–	–			
9-14	H70	–	–			
9-15	77	–	–			
9-16	80	–	–			
9-17	84	–	–			
9-18	86	+	+			
9-19	87	+	+			
9-20	92	–	–			
9-21	762	+	+			
9-22	3830	–	–			
9-23	5469U	+	+			
9-24	D4056	+	+			
9-25	D4078	+	+			
9-26	D4083	+	+			
9-27	B26	+	+			
9-28	B28	–	–			
9-29	B43	–	–			
9-30	B75	–	–			
9-31	B91	+	+			
9-32	P6	–	–			
9-33	P12	–	–			
9-34	P20	+	+			
9-35	P52	–	–			
9-36	P57	+	+			
9-37	P62	–	–			
9-38	P70	+	–			
9-39	P76	–	–			
9-40	P81	+	+			
9-41	P82	–	–			
9-42	P85	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 3 — Concluded.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
9–43	P96	−	−			
9–44	P99	+	+			
9–45	P784	−	−	45	17	37.7

District 5.

6– 1	052	−	−			
6– 2	053	−	−			
6– 3	054	−	−			
6– 4	055	−	−			
6– 5	056	+	+			
6– 6	057	+	+			
6– 7	058	+	+			
6– 8	060	+	+			
9– 9	061	−	−			
6– 10	062	−	−			
6– 11	063	−	−			
6– 12	064	−	−			
6– 13	065	−	−			
6– 14	066	−	−			
6– 15	067	+	+			
6– 16	068	+	+			
6– 17	1–021	−	−			
6– 18	1–027	−	−			
6– 19	1–032	+	−			
6– 20	1–033	−	−			
6– 21	1–034	−	−			
6– 22	1–035	−	−			
6– 23	1–036	+	+			
6– 24	1–037	−	−			
6– 25	1–041	−	−			
6– 26	1–045	+	+			
6– 27	1–059	+	+			
6– 28	1–68	+	+			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 5 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
6- 29	1-93	–	–			
6- 30	1-95	–	–			
6- 31	1-96	+	+			
6- 32	1-97	+	–			
6- 33	1-98	+	+			
6- 34	1-8W11	–	–			
6- 35	1-8W20	+	+			
6- 36	2-087	–	–			
6- 37	2-17	–	–			
6- 38	2-22	–	–			
6- 39	2-24	–	–			
6- 40	2-28	–	–			
6- 41	2-29	–	–			
6- 42	2-31	–	–			
6- 43	2-51	–	–			
6- 44	2-52	–	–			
6- 45	2-56	–	–			
6- 46	2-61	–	–			
6- 47	2-65	–	–			
6- 48	2-67	–	–			
6- 49	2-72	–	–			
6- 50	2-74	–	–			
6- 51	2-75	–	–			
6- 52	2-77	–	–			
6- 53	2-88	–	–			
6- 54	2-?	–	–			
6- 55	3-32	+	+			
6- 56	3-48	+	+			
6- 57	3-97	–	–			
6- 58	3-8W1	+	+			
6- 59	3-8W4	–	–			
6- 60	3-8W7	+	+			
6- 61	3-8W10	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 5 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1–100.	Dilution 1–200.			
6– 62	3–8W23	+	+			
6– 63	4–2	–	–			
6– 64	4–4	–	–			
6– 65	4–7	–	–			
6– 66	4–9	–	–			
6– 67	4–10	–	–			
6– 68	4–11	–	–			
6– 69	4–13	–	–			
6– 70	4–21	–	–			
6– 71	4–30	–	–			
6– 72	4–33	–	–			
6– 73	4–35	–	–			
6– 74	4–42	–	–			
6– 75	4–47	–	–			
6– 76	4–50	–	–			
6– 77	4–66	–	–			
6– 78	4–73	–	–			
6– 79	4–84	–	–			
6– 80	4–85	–	–			
6– 81	4–86	–	–			
6– 82	4–94	–	–			
6– 83	5–050	–	–			
6– 84	5–83	–	–			
6– 85	5–805	–	–			
6– 86	5–1925	+	+			
6– 87	5–1956	+	+			
5– 88	5–2002	+	+			
6– 89	6–5	–	–			
6– 90	6–9	–	–			
6– 91	6–19	–	–			
6– 92	6–20	–	–			
6– 93	6–27	–	–			
6– 94	6–36	–	–			
6– 95	6–43	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 5 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1–100.	Dilution 1–200.			
6– 96	6–44	–	–			
6– 97	6–46	–	–			
6– 98	6–48	–	–			
6– 99	6–60	–	–			
6–100	B01	–	–			
6–101	B02	+	+			
6–102	B03	–	–			
6–103	B04	–	–			
6–104	B05	–	–			
6–105	B06	–	–			
6–106	B08	–	–			
6–107	B09	–	–			
6–108	B010	+	+			
6–109	B011	+	+			
6–110	B012	–	–			
6–111	B013	–	–			
6–112	•B013	+	+			
6–113	B014	–	–			
6–114	B015	+	–			
6–115	B016	–	–			
6–116	B017	+	+			
6–117	B018	–	–			
6–118	B019	–	–			
6–119	B020	–	–			
6–120	B022	–	–			
6–121	B023	–	–			
6–122	B024	+	+			
6–123	B025	+	+			
6–124	B028	–	–			
6–125	B029	–	–			
6–126	B047	+	+			
6–127	B9	–	–			
6–128	B59	+	+			
6–129	B8W5	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 5 — Concluded.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
6-130	B8W15	–	–			
6-131	B8W16	–	–			
6-132	B8W17	–	–			
6-133	Male X044	–	–			
6-134	Male X083	–	–			
6-135	Male X090	–	–			
6-135	Male X5	–	–			
6-137	Male X7	–	–			
6-138	Male X13	–	–			
6-139	Male X14	–	–			
6-140	Male X17	–	–			
6-141	Male XB22	–	–			
6-142	Male X23	–	–			
6-143	Male X40	–	–			
6-144	Male XB49	–	–			
6-145	Male XB90	–	–			
6-146	Male X95	–	–			
6-147	Male X100	–	–			
6-148	Male X8W8	–	–			
6-149	Male X8W19	–	–	149	33	22.1

District 6.

7- 1	1A-5	+	+			
7- 2	1A-16	+	+			
7- 3	1A-48	–	–			
7- 4	1A-800	+	+			
7- 5	1B-11	–	–			
7- 6	1B-23	+	+			
7- 7	1B-46	–	–			
7- 8	1B-120	+	+			
7- 9	1B-124	+	+			
7-10	1B-A299	+	+			
7-11	1B-*0999G	+	+			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 6 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
7-12	1C-10	–	–			
7-13	1C-763	–	–			
7-14	3-4	–	–			
7-15	3-10	–	–			
7-16	3-27	–	–			
7-17	3-39	–	–			
7-18	3-61	–	–			
7-19	3-90	+	–			
7-20	3-94	–	–			
7-21	3-97	–	–			
7-22	4-1	+	+			
7-23	4-14	–	–			
7-24	4-18	–	–			
7-25	4-19	+	+			
7-26	4-45	–	–			
7-27	4-46	+	+			
7-28	4-795	+	+			
7-29	5-3	–	–			
7-30	5-6	–	–			
7-31	5-12	+	–			
7-32	5-21	–	–			
7-33	5-22	–	–			
7-34	5-36	–	–			
7-35	5-98	+	+			
7-36	5-100	–	–			
7-37	6-2	+	–			
7-38	6-3	–	–			
7-39	6-12	–	–			
7-40	6-30	+	+			
7-41	6-32	–	–			
7-42	6-77	–	–			
7-43	6-268	+	+			
7-44	6-A276	+	+			
7-45	8-4	+	+			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 6 — Concluded.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
7-46	8-34	–	–			
7-47	8-807	+	+			
7-48	8-810	+	+			
7-49	9-87	–	–			
7-50	14-5	–	–			
7-51	14-12	–	–			
7-52	Male 11	–	–			
7-53	Male 34	–	–			
7-54	Male 47	–	–			
7-55	Male 85	–	–			
7-56	Male 746	–	–			
7-57	Male 780	–	–			
7-58	Male 781	+	+			
7-59	Male 836	–	–	59	23	38.9

District 7.

5- 1	1	–	–			
5- 2	2	–	–			
5- 3	3	–	–			
5- 4	4	+	–			
5- 5	5	–	–			
5- 6	6	–	–			
5- 7	7	–	–			
5- 8	8	–	–			
5- 9	9	–	–			
5-10	10	–	–			
5-11	11	–	–			
5-12	12	–	–			
5-13	13	–	–			
5-14	14	–	–			
5-15	15	–	–			
5-16	16	–	–			
5-17	17	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 7 — Concluded.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1–100.	Dilution 1–200.			
5–18	18	+	–			
5–19	19	–	–			
5–20	20	–	–			
5–21	21	–	–			
5–22	22	+	–			
5–23	23	–	–			
5–24	24	–	–			
5–25	25	–	–			
5–26	26	–	–			
5–27	27	–	–			
5–28	28	–	–			
5–29	29	–	–			
5–30	30	–	–			
5–31	31	–	–			
5–32	32	–	–			
5–33	33	-	-			
5–34	34	–	–			
5–35	35	–	–			
5–36	36	–	–			
5–37	37	–	–			
5–38	38	–	–			
5–39	39	–	–			
5–40	40	–	–			
5–41	41	–	–			
5–42	42	–	–			
5–43	Male 1	–	–			
5–44	Male 2	–	–			
5–45	Male 7	–	–	45	3	6.6

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4- 1	139	–	–			
4- 2	140	+	–			
4- 3	141	–	–			
4- 4	142	–	–			
4- 5	143	–	–			
4- 6	145	–	–			
4- 7	146	–	–			
4- 8	147	+	–			
4- 9	148	–	–			
4- 10	150	–	–			
4- 11	151	–	–			
4- 12	152	–	–			
4- 13	154	–	–			
4- 14	155	–	–			
4- 15	157	–	–			
4- 16	158	–	–			
4- 17	159	–	–			
4- 18	160	–	–			
4- 19	161	–	–			
4- 20	162	–	–			
4- 21	163	–	–			
4- 22	164	–	–			
4- 23	165	+	–			
4- 24	166	–	–			
4- 25	167	+	+			
4- 26	168	+	+			
4- 27	169	–	–			
4- 28	171	–	–			
4- 29	172	+	+			
4- 30	173	+	–			
4- 31	174	–	–			
4- 32	175	–	–			
4- 33	176	–	–			
4- 34	177	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4- 35	178	–	–			
4- 36	179	–	–			
4- 37	180	–	–			
4- 38	181	–	–			
4- 39	182	+	+			
4- 40	183	–	–			
4- 41	184	–	–			
4- 42	185	–	–			
4- 43	187	+	+			
4- 44	188	–	–			
4- 45	189	–	–			
4- 46	190	–	–			
4- 47	191	–	–			
4- 48	193	+	+			
4- 49	194	–	–			
4- 50	195	–	–			
4- 51	196	–	–			
4- 52	198	+	+			
4- 53	199	+	+			
4- 54	201	–	–			
4- 55	202	–	–			
4- 56	203	+	+			
4- 57	205	–	–			
4- 58	206	–	–			
4- 59	208	–	–			
4- 60	209	–	–			
4- 61	210	–	–			
4- 62	211	–	–			
4- 63	212	+	+			
4- 64	213	+	+			
4- 65	214	–	–			
4- 66	216	–	–			
4- 67	217	–	–			
4- 68	218	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Continued.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4- 69	220	+	+			
4- 70	221	–	–			
4- 71	222	+	+			
4- 72	223	–	–			
4- 73	224	–	–			
4- 74	226	–	–			
4- 75	227	–	–			
4- 76	230	–	–			
4- 77	231	–	–			
4- 78	232	–	–			
4- 79	233	–	–			
4- 80	234	–	–			
4- 81	235	–	–			
4- 82	236	–	–			
4- 83	237	–	–			
4- 84	240	–	–			
4- 85	241	–	–			
4- 86	242	–	–			
4- 87	243	–	–			
4- 88	244	–	–			
4- 89	245	–	–			
4- 90	246	–	–			
4- 91	247	–	–			
4- 92	249	+	+			
4- 93	250	–	–			
4- 94	251	–	–			
4- 95	252	–	–			
4- 96	253	–	–			
4- 97	254	–	–			
4- 98	255	–	–			
4- 99	256	+	+			
4-100	257	–	–			
4-101	259	–	–			
4-102	260	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4-103	262	−	−			
4-104	263	−	−			
4-105	264	−	−			
4-106	265	−	−			
4-107	266	−	−			
4-108	268	+	+			
4-109	269	−	−			
4-110	270	−	−			
4-111	271	−	−			
4-112	272	−	−			
4-113	274	−	−			
4-114	275	−	−			
4-115	276	−	−			
4-116	278	+	+			
4-117	279	−	−			
4-118	281	−	−			
4-119	282	+	+			
4-120	284	−	−			
4-121	285	+	+			
4-122	286	+	+			
4-123	287	−	−			
4-124	288	−	−			
4-125	289	−	−			
4-126	290	−	−			
4-127	291	−	−			
4-128	293	−	−			
4-129	294	−	−			
4-130	295	−	−			
4-131	296	−	−			
4-132	297	−	−			
4-133	298	+	+			
4-134	299	−	−			
4-135	300	+	−			
4-136	301	−	−			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4-137	302	−	−			
4-138	303	−	−			
4-139	304	+	+			
4-140	305	−	−			
4-141	306	−	−			
4-142	307	−	−			
4-143	308	+	+			
4-144	310	+	+			
4-145	311	−	−			
4-146	312	−	−			
4-147	313	−	−			
4-148	314	−	−			
4-149	315	+	+			
4-150	316	−	−			
4-151	317	−	−			
4-152	318	−	−			
4-153	319	−	−			
4-154	320	−	−			
4-155	321	+	+			
4-156	323	+	+			
4-157	326	−	−			
4-158	327	−	−			
4-159	328	−	−			
4-160	329	−	−			
4-161	330	−	−			
4-162	331	+	+			
4-163	332	+	+			
4-164	335	−	−			
4-165	336	−	−			
4-166	337	+	−			
4-167	338	−	−			
4-168	339	−	−			
4-169	340	−	−			
4-170	341	−	−			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test. Dilution 1–100.	Agglutination Test. Dilution 1–200.	Total Number in Flock.	Total Number infected.	Per Cent. infected.
4–171	342	–	–			
4–172	343	–	–			
4–173	344	–	–			
4–174	345	–	–			
4–175	346	–	–			
4–176	347	–	–			
4–177	348	–	–			
4–178	349	–	–			
4–179	350	–	–			
4–180	352	–	–			
4–181	354	–	–			
4–182	355	–	–			
4–183	356	–	–			
4–184	358	–	–			
4–185	359	–	–			
4–186	360	–	–			
4–187	361	–	–			
4–188	362	–	–			
4–189	363	+	–			
4–190	364	+	+			
4–191	365	–	–			
4–192	366	–	–			
4–193	367	–	–			
4–194	368	–	–			
4–195	369	+	+			
4–196	370	–	–			
4–197	371	+	+			
4–198	372	–	–			
4–199	374	–	–			
4–200	375	–	–			
4–201	376	–	–			
4–202	378	+	+			
4–203	379	–	–			
4–204	380	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Continued.

Laboratory Number.	Hen Number.	AGGLUTINATION TEST.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4-205	381	−	−			
4-206	382	−	−			
4-207	384	−	−			
4-208	385	−	−			
4-209	386	−	−			
4-210	387	−	−			
4-211	392	−	−			
4-212	393	+	−			
4-213	394	+	+			
4-214	396	−	−			
4-215	399	+	+			
4-216	Y3	−	−			
4-217	Y11	−	−			
4-218	Y12	−	−			
4-219	Y14	−	−			
4-220	Y16	−	−			
4-221	Y23	−	−			
4-222	Y26	+	−			
4-223	Y33	−	−			
4-224	Y38	−	−			
4-225	Y39	−	−			
4-226	Y42	−	−			
4-227	Y44	−	−			
4-228	Y45	−	−			
4-229	Y46	−	−			
4-230	Y47	−	−			
4-231	Y48	−	−			
4-232	Y49	−	−			
4-233	Y56	−	−			
4-234	Y57	−	−			
4-235	Y58	−	−			
4-236	Y60	−	−			
4-237	Y61	−	−			
4-238	Y64	−	−			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4-239	Y65	–	–			
4-240	Y66	–	–			
4-241	Y67	–	–			
4-242	Y70	–	–			
4-243	Y73	–	–			
4-244	Y77	–	–			
4-245	Y80	–	–			
4-246	Y81	–	–			
4-247	Y82	–	–			
4-248	Y83	–	–			
4-249	Y84	–	–			
4-250	Y85	–	–			
4-251	Y89	+	–			
4-252	Y92	–	–			
4-253	Y93	–	–			
4-254	Y94	+	–			
4-255	Y95	–	–			
4-256	Y96	–	–			
4-257	Y97	–	–			
4-258	Y98	–	–			
4-259	Y99	–	–			
4-260	Y100	–	–			
4-261	Y101	–	–			
4-262	Y104	–	–			
4-263	Y106	–	–			
4-264	Y110	–	–			
4-265	Y111	–	–			
4-266	Y112	–	–			
4-267	Y115	–	–			
4-268	Y120	–	–			
4-269	Y121	+	+			
4-270	Y122	+	+			
4-271	Y123	–	–			
4-272	Y124	–	–			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 8 — Concluded.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
4-273	Y126	−	−			
4-274	Y127	−	−			
4-275	Y128	−	−			
4-276	Y129	+	−			
4-277	Y130	+	+			
4-278	Y131	−	−			
4-279	Y133	−	−			
4-280	Y135	−	−			
4-281	Y136	−	−			
4-282	Y137	−	−			
4-283	Y138	−	−			
4-284	Y397	−	−	284	50	17.6

District 10.

Laboratory Number.	Hen Number.	Dilution 1-100.	Dilution 1-200.	Total Number in Flock.	Total Number infected.	Per Cent. infected.
1- 1	101	−	−			
1- 2	103	−	−			
1- 3	104	−	−			
1- 4	215	−	−			
1- 5	551	−	−			
1- 6	552	−	−			
1- 7	553	−	−			
1- 8	554	−	−			
1- 9	556	−	−			
1-10	558	−	−			
1-11	560	−	−			
1-12	561	−	−			
1-13	562	−	−			
1-14	563	−	−			
1-15	564	−	−			
1-16	565	+	+			
1-17	566	−	−			
1-18	567	−	−			
1-19	569	−	−			

Chart showing Results of Agglutination Tests, etc. — Continued.

District 10 — Continued.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
1-20	570	–	–			
1-21	573	–	–			
1-22	574	–	–			
1-23	577	–	–			
1-24	581	–	–			
1-25	583	–	–			
1-26	584	–	–			
1-27	588	–	–			
1-28	589	–	–			
1-29	591	–	–			
1-30	594	+	+			
1-31	598	–	–			
1-32	599	–	–			
1-33	601	–	–			
1-34	604	–	–			
1-35	606	–	–			
1-36	611	+	+			
1-37	613	+	+			
1-38	615	+	+			
1-39	617	–	–			
1-40	620	–	–			
1-41	621	–	–			
1-42	626	+	–			
1-43	631	–	–			
1-44	634	–	–			
1-45	637	–	–			
1-46	638	–	–			
1-47	644	–	–			
1-48	646	–	–			
1-49	657	–	–			
1-50	658	–	–			
1-51	660	–	–			
1-52	661	–	–			
1-53	665	–	–			

Chart showing Results of Agglutination Tests, etc. — Concluded.

District 10 — Concluded.

Laboratory Number.	Hen Number.	Agglutination Test.		Total Number in Flock.	Total Number infected.	Per Cent. infected.
		Dilution 1-100.	Dilution 1-200.			
1-54	667	–	–			
1-55	673	–	–			
1-56	674	–	–			
1-57	675	–	–			
1-58	676	–	–			
1-59	679	–	–			
1-60	680	–	–			
1-61	682	–	–			
1-62	683	–	–			
1-63	686	–	–			
1-64	687	–	–			
1-65	688	+	+			
1-66	690	–	–			
1-67	693	–	–			
1-68	695	–	–			
1-69	696	–	–			
1-70	697	–	–			
1-71	698	–	–			
1-72	700	–	–	72	7	9.7

DISTRIBUTION OF INFECTION AND TYPES OF STOCK INFECTED.

A study of the map and chart indicates that the infection is distributed throughout Massachusetts. It should be borne in mind, however, that this represents the work of but a short time on representative breeding flocks. A further study conducted along the same lines would undoubtedly result in furnishing data which would indicate that there exists throughout the State a general infection.

We have realized that there are several types of poultry work conducted in Massachusetts, *i.e.*, the management of poultry plants along lines best suited to the rearing of utility and fancy stock. In the data we are reporting are included the results from tests made on both types. Many poultrymen will say that they have bought their stock from the best that can be had, but this is no protection against infection. In way of illustration we might say that it has been the good fortune of the Department in the spring of 1914 and 1915 to be associated with some of the most practical and most enthusiastic poultry raisers in the State of Massachusetts in both lines. The results obtained indicate that infection is found in all types of breeding birds, — utility, fancy, birds raised in the State, birds brought into the State from other States, — and we have found it in stock which has been sent in from Europe.

Results of Application of these Methods for preventing and eradicating Bacillary White Diarrhea of Young Chicks.

After studying the charts it can be seen that in all districts of Massachusetts the organism has been found in young chicks, and also laying hens have been tested and found to be infected. For example, in District 1 a representative flock contained 50 per cent. of positive reactors, which would indicate that throughout this whole district the infection was general. In District 5, representative flocks showed that 22.1 per cent. of breeding birds were infected. From this we are led to believe that there is only a moderate degree of infection, but examination of dead chicks from this area of the State indicates heavy infection. In District 8, 17 per cent. of the breeding birds were infected in the representative flock chosen. From our work on chick examinations we are led to believe that this is indicative of the conditions in this locality. These results need no comment. They at least show that bacillary white diarrhea is widely distributed. They show, also, that being so generally scattered over the various areas of the State poultrymen should be made aware of its prevalence and willing to co-operate in every way to stamp it out.

It can be easily seen that in order to do this eggs used for hatching must come from sound, uninfected stock. This really is the only basis for improvement. The infected individual must be sought and eliminated from the breeding flock.

At the present time poultry raisers may feel that their labors are hopeless if white diarrhea should make its appearance in their young chicks. It is not the object of this paper to discourage present and prospective poultry raisers, but, with our methods of study, detection and control of this disease, to encourage greater effort in the industry. By thorough co-operation of poultrymen and laboratory workers a great improvement in raising young chicks must follow.

This infection is readily transmitted through eggs, day-old chicks and mature stock. Therefore, to insure against the infection poultrymen should buy only from stock known to be free from the infection. If all breeders would have their birds tested, and infected birds eliminated, their customers would be insured against buying infected stock. In other words, all stock should bear a stamp indicating tested and found negative.

Wherever the blood test has been made and the positive reactors eliminated a marked improvement has resulted in the young chicks hatched thereafter. Every poultryman co-operating with the Department thus for the improvement of his flock conditions by these methods has been convinced that conditions have improved. All are unanimous in placing their stamp of approval upon the work thus far conducted, and all hope the work in connection with the problem of eradication may be carried through to a successful finish.

We believe that the results both of our scientific work and of its practical application may be confidently depended upon and that examination will convince even the most skeptical. Poultrymen who have suffered great losses will be unanimous in supporting the views of workers in this Department; *i.e.*, that it is possible to rid Massachusetts for the most part of this disease, and that a campaign should be organized against bacillary white diarrhea infection.

The problem of eradicating *Bacterium pullorum* infection involves organization, clerical detail and a constant observation of the laws governing the study and progress of disease. It is a problem in practical pathology, and can be solved only by the pathologist and poultryman co-operating. The methods of the laboratory play an important part in the campaign. Therefore, intelligent, efficient and conscientious co-operation of all concerned is essential for success.

To efficiently handle the situation the work of the campaign must be centered in a strictly scientific atmosphere, since it requires pathological organization, efficient laboratory analyses and record keeping based on such knowledge. Therefore, if funds are provided, the Department of Veterinary Science with its laboratory equipment already established would be in a position to continue the work to help eliminate domestic fowls in the State of Massachusetts carrying *Bacterium pullorum* infection, which has been the cause of great mortality of young chicks.

BULLETIN No. 164 NOVEMBER, 1915

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

I.

Substitutes for Milk in the Rearing of Dairy Calves

II.

The Cost of Rearing a Dairy Cow

By J. B. LINDSEY

This bulletin contains the results of our observations covering a series of years in the raising of calves for dairy purposes. In Part I. is described the method followed and the cost of raising calves to six or eight months of age on skim milk, ordinary grains and hay; also the testing of several proprietary calf meals as milk substitutes, and our experience with a number of our own calf meal preparations. In Part II. is given the total food cost of raising twenty dairy heifers, together with data from other sources, relative to food and other costs. It is believed that $75 to $85 represents the total cost of raising the average dairy heifer until she reaches the age of two years.

Requests for bulletins should be addressed to the
Agricultural Experiment Station,
Amherst, Mass.

Massachusetts Agricultural Experiment Station.

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Approved by the State Board of Publication.

DEPARTMENT OF CHEMISTRY.

PART I.

SUBSTITUTES FOR MILK IN THE REARING OF DAIRY CALVES.

BY J. B. LINDSEY.

INTRODUCTION.

With plenty of whole or skim milk available the rearing of dairy calves is a comparatively simple matter, providing one pays attention to such important details as clean pails, clean stalls, clean bedding and uses care in feeding. In such a State as Massachusetts, however, the price of whole milk renders its economical use in any quantity as a food for calves prohibitive, while skim milk is to be had only in quite limited amounts except in the immediate vicinity of the comparatively few creameries located west of the Connecticut River.

This lack of milk renders it very necessary that some substitute be provided if the dairyman is to raise his heifer calves in a satisfactory way. It is well known that the stomach of the calf is very sensitive during the first few months of its life, and it is doubtful if any substitute can be found or compounded which will completely take the place of milk. Numerous substitutes in the form of calf meals have been suggested, among which may be mentioned Liebig's Calf Soup,[1] Hansen's Potato Meal and Barley Malt,[1] and Hayward's Calf Meal.[2] Several proprietary mixtures are also to be noted, such as Lactina Suisse,[3] made in Switzerland; Bibby's Cream Equivalent, made in England; Blatchford's, Schumacher's and other calf meals, made in this country.

RESULTS OF EXPERIMENTS MADE AT THIS STATION.[4]

In the experiments reported, whole milk has been charged at 5 cents a quart, skim milk at .65 cent a quart, ordinary grain mixtures at 1.6 cents a pound, hay at $10 a ton,[5] and the calf meals at market price or actual cost of preparation.

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[1] Kellner's Ernährung d. Landw. Nutzthier., sixth ed., p. 283.

[2] Penn. Exp. Sta. Bul. 60.

[3] Cornell Exp. Sta. Bul. 269.

[4] Including citations from other experimenters.

[5] Assumed to be the cost of production.

I. Calves fed Whole Milk, Skim Milk and Ordinary Grains.

The station began to rear its own dairy calves for the purpose of replenishing the station herd as early as 1903. The method at that time consisted in feeding whole milk for the first week or ten days, then gradually substituting skim milk, until at the end of a month or six weeks the whole milk was entirely removed. When the calf was a month or six weeks of age a little flour wheat middlings was stirred into the milk, and a dry grain mixture was also put before the animals. This mixture usually consisted of equal parts, by weight, of wheat bran, flour middlings and corn meal. As the calves grew, and took increased amounts of dry grain, the addition of middlings to the milk was omitted. The skim-milk diet was usually continued until the animals were from six to seven or eight months of age, the supply of skim milk at the time being liberal.

The calves were usually dropped in the autumn and went to pasture the next spring.

The following record shows the amounts of the several feeds consumed, the total food cost, the cost of food for each pound of gain, and the total gain in weight: —

Results.

Calf.	Whole Milk (Pounds).	Skim Milk (Pounds).	Grain (Pounds).	Rowen (Pounds).	Total Food Cost.	Cost of Food per Pound Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Maud,	164	4,974	301	986	$28 18	7.7	365	1.30	281
Susie,	143	4,326	249	505	22 79	6.9	333	1.40	237
Betty,	160	3,796	230	858	23 05	7.0	328	1.40	237
Mibbs,	264	5,228	301	1,059	31 96	8.6	370	1.32	280
Lena,	200	2,625	247	420	18 52	6.5	287	1.43	200
Red III.,	169	4,400	132	263	20 52	–	–	–[1]	197
Betty II.,	138	3,079	60	198	14 35	6.1	235	1.37	171
Fancy II.,	112	4,581	137	390	20 46	8.7	235	.91	258
Fancy III.,	180	3,765	238	545	23 66	9.5	250	.94	266
Amy W.,	110	3,793	114	312	17 29	8.6	200	.92	218
Average,	164	4,145	201	553	$22 08	7.7	289	1.22	235

[1] Not weighed at end of trial.

The above tabulation shows that the 10 calves, when fed on a combination of whole and skim milk, hay and ordinary grains for an average of 7.8 months (235 days) after birth, made an average daily gain of 1.22 pounds at a cost of $22.08 a head.

It is understood that such a liberal feeding with skim milk could not be followed excepting in those localities where skim milk is in liberal supply. Thus Fraser (Bulletin No. 164, Illinois Station) states that in the interest of economy all milk may be removed after eight weeks, and the animals placed upon a diet of mixed grain, clover and alfalfa hay. His experiments averaged 150 pounds whole milk and 450 pounds skim milk for each calf. He admits, however, that "when it is possible, more milk than herein recommended should be fed, as it is always best to keep the calf in a good growing condition from its birth to maturity. Calves thus fed were always healthy, and while they were rather thin, from the time they were eight to twelve or fifteen weeks old, they grew into good condition later, and made fine healthy heifers."

Morse[1] in 1898 fed young calves whole milk, skim milk and flaxseed jelly, the latter being used as a supplement to skim milk in replacing the milk fat. The average daily gain of 8 calves for five months was 1.37 pounds, and the total cost for each calf was $9.57. Whole milk was valued at $1, skim milk at 20 cents, and flaxseed meal at $3.25 a hundred pounds, much less than at present. Morse states that "flaxseed meal cannot be used with economy except in the earliest stages of growth, — the first two or three months, — and whole milk should be discontinued as soon as possible."

Wing [2] fed 12 calves until five months of age on skim milk, hay and grain, and found that they made an average gain of 1.5 pounds daily at a cost of about 5 cents a pound. He figured his skim milk at 15 cents a hundred, hay at $10 a ton and grain at about $30 a ton. He further concluded that the food cost of rearing a calf to five months of age is from $12 to $15. The fact that the calves fed under his supervision made a somewhat larger daily gain than ours at a less daily cost is due partly to the less price charged for the skim milk and to the shorter period (five instead of eight months). The older the animal the greater the cost of a pound of growth.

II. Calves fed Hayward's Calf Meal.

This meal was compounded as follows: —

	Pounds.
Finely ground wheat or cheap flour,	30
Cocoanut meal,	25
Nutrium,	20
Linseed meal,	10
Blood flour,	2

Present cost a pound, 4.6 cents.

Hayward employed whole wheat ground by the local miller. St. Louis flour can also be used. Cocoanut meal [3] contains some 21 per cent. protein and 9 per cent. fat. Nutrium [1] is evaporated skim milk ground to a powder. Blood flour is prepared especially by Swift & Co. and Armour & Co., and costs about 3 cents a pound at Chicago.

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[1] Bul. 58, N. H. Exp. Sta.

[2] Bul. 269, Cornell Exp. Sta. (1909).

[3] Sold by the Oil Seeds Co., 35 South William Street, New York.

Method of Feeding. — The finely ground calf meal was stirred into very hot water at the rate of 1 pound of meal to 8 pounds of water. The gruel was fed when milk-warm. Hayward used a calf feeder, but in our case the animals were taught to drink the gruel. Two thrifty grade Jersey calves were fed whole milk for about nine days, then skim milk and calf-meal gruel gradually substituted, until at the end of three weeks the whole milk was entirely removed. At the end of five weeks the calves were receiving only the calf-meal gruel. Calf I. was kept on the gruel 143 days and Calf II. 101 days. Calf II. was not as robust as Calf I., and suffered a severe attack of indigestion during the trial, which rendered it necessary to take away a considerable portion of the meal and to substitute skim milk until the end of the experiment. While the calves did not have as sleek an appearance as if raised on a whole milk diet, they were in thrifty growing condition, and at the end of the trial appeared quite vigorous.

Results.

CALF.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Total Food Cost.	Cost of Food per Pound Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Calf I., ...	202	130	374	$22 24	9.3	240	1.35	178
Calf II., ...	152	352	306	18 64	9.8	190	1.10	169
Hayward's average with 12 calves, .	121	–	186	11 34	9.6	118	1.18	102

The table shows that Calf I. made an average daily gain of 1.35 pounds, and Calf II., 1.10 pounds, which was satisfactory. The animals were nearly six months old when the trial was ended, Calf I. weighing 310 pounds and Calf II., 260 pounds. The total food cost and the cost of food per pound of live weight gained was rather more than desired. The chief objection to this calf meal is its cost, due to the use of the evaporated skim milk.

The table also includes the average results secured by Hayward with 12 calves from the first few days after they were dropped until the end of the experiment, which averaged 102 days. The cost of the milk and calf meal has been figured by us at 5 cents a quart and 4.6 cents a pound respectively. The 12 calves varied from 53 to 100 pounds at the beginning, and from 127 to 254 pounds in weight at the close, of the trial. The average daily gain and food cost per pound of gain do not vary greatly from our results. Hayward comments upon his results as follows: —

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[1] Sold by the National Nutrient Co., Jersey City, N. J. Other skim-milk powders are made by Merrill Soule Co., Syracuse, N.Y., and cost 12 or more cents a pound. Its cost renders its use in any large amount hardly economical.

> While calves made but slight gains when first put upon the calf meal, later they made as rapid gain as two which were fed a ration of skim milk to which some grain was added. Those that were fed the calf-meal ration were so nearly like the skim-milk calves in condition that it was impossible to tell from appearances which were and which were not being fed the calf meal. . . .
>
> Those that have been raised upon the calf meal have not been troubled with scours to any extent, and in this respect no difference could be seen between the calf-meal and the skim-milk calves. . . .
>
> Some calves appeared to be much more vigorous and thrifty than others, would take more kindly to the calf meal and do better than their less hardy neighbors.

III. Calves fed Schumacher's Calf Meal.

This meal, according to the manufacturers, is made from the residues in the preparation of puffed grains, wheat and oat meals, together with flaxseed meal, cottonseed meal and dried casein. It costs substantially 3.2 cents per pound at retail. It contains 15 to 17 per cent. protein, not much over 1.5 per cent. fiber, some 7 per cent. fat, 2 per cent. ash and about 60 per cent. of starchy matter.

Method of Feeding. — This meal was fed to two grade Holstein calves and one grade Jersey calf. Instead of following the directions outlined by the manufacturers, there was added to each 4 ounces of the meal a little cold water, and the material stirred to a paste. Then very hot water was added, allowing substantially 1 quart of water to each 4 ounces of meal, the mixture thoroughly stirred, allowed to cool and fed milk-warm. The general method of feeding these three calves consisted in giving whole milk for the first week, then gradually substituting skim milk and the calf-meal gruel. The whole milk was entirely replaced at the end of two weeks and the skim-milk and calf-meal gruels substituted. In case of these three calves 5 quarts of skim milk were fed daily and continuously as a basal food, together with 4 quarts of the calf-meal gruel. In addition, after some six weeks, dry calf meal and rowen were placed before the calves, and when some three to four months old the calves were eating 1 pound of the dry meal daily, at which time the calf-meal gruel and the skim milk were gradually removed.

Results.

Calf.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Rowen (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
No. II., ...	–	1,120	207	266	$11 31	8.3	135	.90	153
Samantha II., . . .	58	1,377	155	167	11 55	7.9	147	1.10	134
Daisy II., ...	46	1,600	213	257	13 96	8.5	165	1.02	162

The calves were in good condition at the end of the experiment and had made a reasonably fair gain in weight. They probably would have done well if the amount of skim milk fed daily had been reduced from 5 to 4 quarts, and the calf-meal gruel correspondingly increased.

Wing,[1] at the Cornell Station, reports the results of two experiments with feeding Schumacher's Calf Meal. The directions for feeding the calf meal as put out by the company were followed as accurately as circumstances would permit.

Wing's Results (Average per Calf).

Number of Calves.	Total Food Cost.[2]	Cost of Food per Pound of Gain (Cents).	Total Average Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
6, ...	$12 14	8.1	150.1	1.25	120
4, ...	14 69	9.0	163.0	1.10	150

Wing remarks that "Schumacher's Calf Meal seems to be the best commercial substitute, in the nature of grain, for skimmed milk on the market at the present time (1909). It does not appear to be a complete substitute for skimmed milk, yet the gains from the use of this meal are good, and the cost of a pound of gain is fairly low."

IV. Calves fed Blatchford's Calf Meal.

We have not sufficient data to warrant any positive expression of opinion, it being fed to one calf only, — a vigorous grade Holstein. It did not seem advisable to feed the meal exclusively for the first three months of the calf's life, hence 4 quarts of skim milk were fed daily, and, in addition, what meal the calf would take, made into a gruel with hot water, and the mixture fed lukewarm. After it had reached the age of three months the milk was removed and the calf meal was given as the only food for six weeks, during which time it gained an average of 1.15 pounds daily, and did not suffer any digestive disturbances. This calf has made an excellent cow, and is known as Samantha. It was noted that the calf at first objected to the odor or taste of the meal, although no serious difficulty was encountered in inducing the animal to take it. At the present time its cost is about 3½ cents a pound, and it is composed, according to the manufacturers, of locust bean meal, wheat flour, flaxseed and linseed meals, cocoanut meal, ground beans and peas, cocoa shells, recleaned cottonseed meal, fenugreek and salt.

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[1] Already cited.

[2] Whole milk was charged at $1.65 and skim milk at 15 cents a hundred; hay at $10 and grain mixture at $29.55 a ton; the calf meal at $3.50 a hundred.

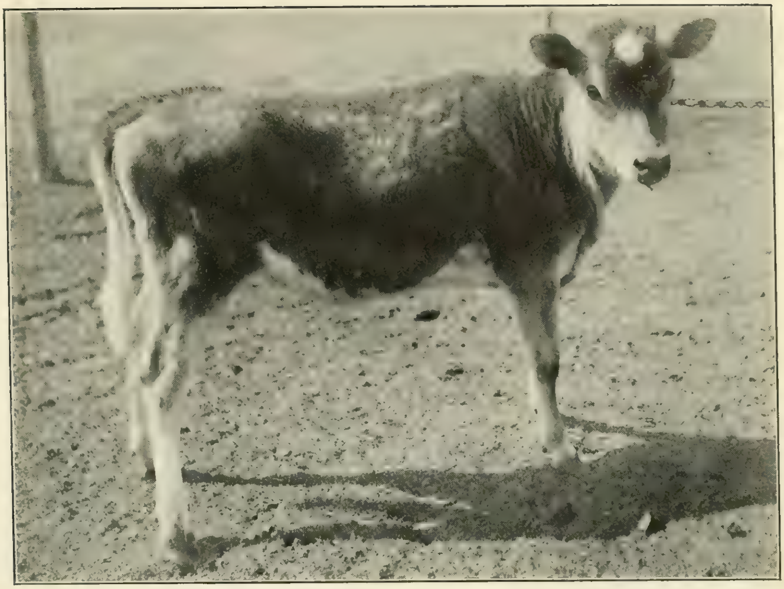

Fig. 1. — Daisy II. Schumacher's calf meal.

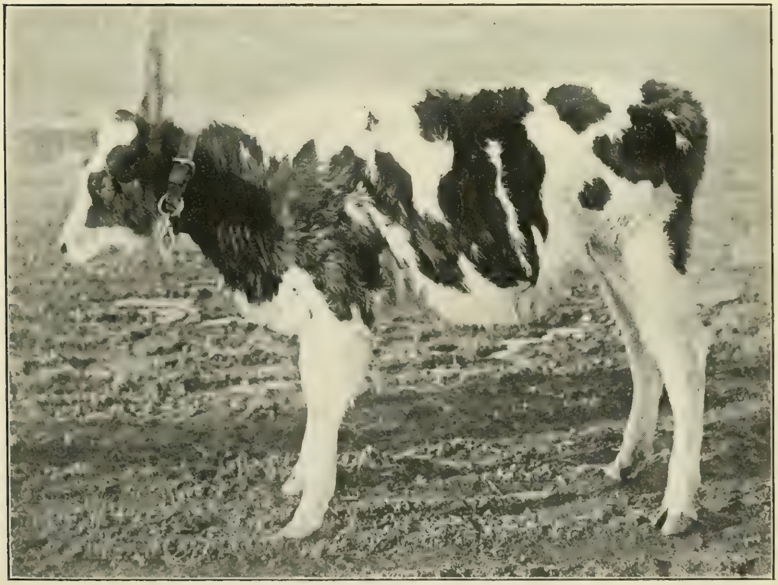

Fig. 2. — Samantha II. Schumacher's calf meal.

Wing[1] fed the Blatchford meal to two Holstein and two Shorthorn calves, the average weight of the four at birth being 72 pounds. "The calf gruel was made by mixing the meal with a little cold water to avoid lumps, then enough hot water was added to make a sufficient gruel for the number of feeds required. The gruel was cooled and warmed again to 90° to 100° F. before feeding if too cold. When the meal was first fed to the young calf a tablespoonful of the meal was mixed into gruel in this way and added to the whole milk. The whole milk was then gradually reduced until the calf took the meal gruel entirely. The amount of calf meal fed per day varied from a tablespoonful, fed in the beginning with the whole milk, up to 2¼ pounds per day."

Results of Wing's Trials.

CALF NUMBER.	Whole Milk (Pounds).	Blatchford's Calf Meal (Pounds).	Hay (Pounds).	Grain (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
2, ...	302	234	232	90	$16 83	11.4	148	.99	150
9, ...	213	268	290	90	17 00	15.7	108	.72	150
14, ...	144	273	407	130	17 26	13.2	131	.87	150
18, ...	168	306	303	125	18 39	13.5	136	.91	150

It is certain that in case of these four calves the gain per day is low and the food cost per day is high. Wing concluded that "Blatchford's Calf Meal, while good enough for raising fair-sized calves, is too expensive to feed ordinarily."[2]

V. CALVES FED BIBBY'S CREAM EQUIVALENT.

This meal is prepared by J. Bibby & Sons, Liverpool, Eng., and contains, according to the manufacturer's statement, linseed and linseed cake, tapioca flour, sago flour, rice polish starch, locust bean and salt. From the high percentage of fat present considerable flaxseed meal must be used. Its cost is a trifle over 4 cents a pound. It was tried on three calves (one a delicate Jersey and two vigorous grade Holsteins). The Jersey calf was fed whole and skim milk for three weeks, at the end of which the calf-meal gruel was gradually added. Four quarts of skim milk were fed daily throughout the trial which lasted 164 days. The maximum amount of calf meal fed daily as gruel was 1 pound, 5 ounces.

The Holsteins were also given whole and skim milk for the first three weeks and then began the feeding of the calf gruel. The maximum amount of meal fed as gruel was 18 ounces daily. Four quarts of skim milk were fed daily throughout the trial, lasting 140 days. The gruel was prepared in the usual way by adding a little cold water to the dry meal and then approximately 1 quart of boiling water for each 3½ ounces of meal. The mixture was allowed to stand until cool, and was always warmed to 90° to 100° F. before feeding. In addition to the calf meal fed as a gruel, after the first three months the dry meal and rowen were placed before the animals and they soon began to eat these readily. At the end of the 140 days the calves were eating daily 4 quarts of skim milk, 18 to 21 ounces of calf meal as gruel, 8 ounces of dry calf meal and 5 pounds of rowen.

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[1] Already cited.

[2] Calf meal cost 4 cents a pound at the time.

Results.

Calf.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Rowen (Pounds).	Total Cost (Dollars).	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Jersey,	133	1,420	168[1]	305	$15 11	8.4	179.5	1.13	164
Holstein,	106	1,237	125	235	12 51	7.1	174.5	1.30	140
Holstein,	112	1,240	112	230	11 62	7.1	163.0	1.20	140

[1] Thirty-six pounds of another calf meal.

3)517.0 3.6
172.3 .21

The calves did very well on this diet and were in good condition at the end of the trial. It would have been more satisfactory, from an experimental standpoint, if they had been given rather more of the calf meal and less of the milk; they appeared, however, to be taking all of the meal that they could care for and keep in good condition.

VI. Calf Meals prepared at this Station.

This station has compounded a number of calf meals and fed them to calves. The object was to use feedstuffs that were available in the ordinary markets at reasonable prices, and that were free from an excess of fiber and easily digested.

Lindsey's Calf Meal I.

Ingredients: —
10 pounds fine corn meal.
10 pounds flour middlings.
15 pounds flaxseed meal.
10 pounds cheap flour.
5 pounds glucose sugar.
1 pound salt.

Cost, 3.2 cents a pound.

The corn meal, flour middlings and cheap flour were easily obtainable. The flaxseed meal, procured of linseed oil manufacturers, was used because of the favorable effect of its protein and of its large percentage of

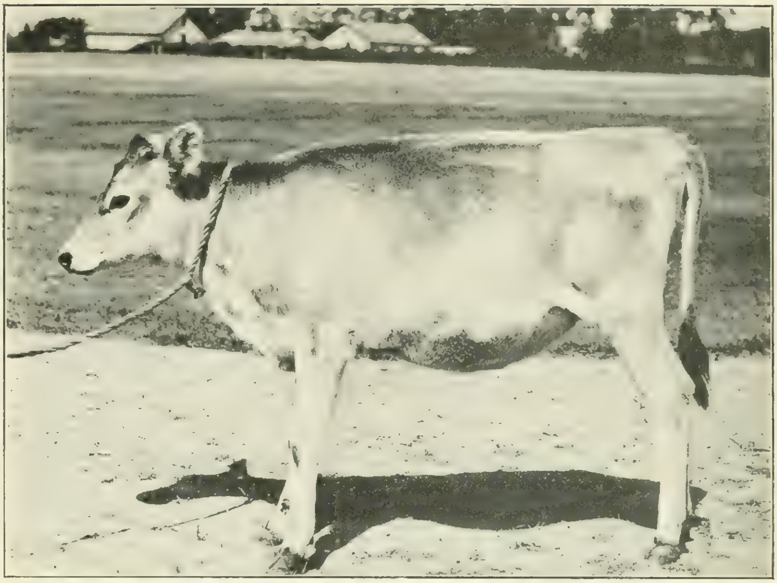

Fig. 3. — Cecile II. Bibby's cream equivalent.

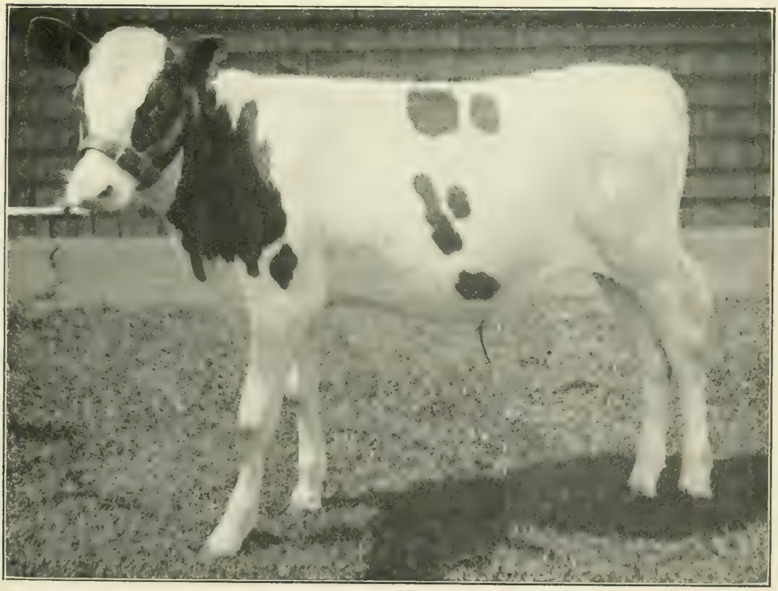

Fig. 4. - Holstein steer. Bibby's cream equivalent.

fat. The glucose sugar was incorporated to impart a pleasing taste, and because it could be readily assimilated. This mixture was fed to two grade calves.

Results.

CALF.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Rowen (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Grade Holstein I., . .	211	935	185	256	$14 86	11.4	130.0	.90	149
Grade Ayrshire III., . .	120	1,467	189	199	14 21	9.4	150.5	1.04	144

The grade Holstein received, during the first part of the trial, 47 pounds of Schumacher's Calf Meal, and after that the station calf meal. It scoured badly when young, and hence did not make very satisfactory gains. The grade Ayrshire was not affected at all with scours and came along nicely. These calves received 5 quarts of skim milk and as high as 1 pound of calf meal as gruel daily. The calf meal was considered fairly satisfactory, although the cost of a pound of growth was too high. The glucose sugar is not on the market as a food for stock; it was procured through the Corn Products Refining Company of New York.

Lindsey's Calf Meal II.

Ingredients: —
25 pounds ground oat flakes.
15 pounds flaxseed meal.
8 pounds cheap flour.
2 pounds glucose sugar.
1 pound salt.

Cost, 3.7 cents a pound.

The oat flakes were the ordinary oat meal used for human food. It was purchased in bags of 96 pounds in weight.

Results.

CALF.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Rowen (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Pure Jersey II., ...	–	1,164	226	110	$12 40	7.2	172	1.03	167
Pure Jersey IV., ...	34	1,404	249	305	15 74	8.2	193	.90	203
Pure Jersey V., ...	63	1,530	233	248	15 90	7.4	214	1.20	180

Calves II. and IV. were pure-bred Jersey heifers sent by a breeder. They were some ten to fourteen days old when received, and it did not seem necessary to feed them much, if any, whole milk. Calf V. was a pure-bred Jersey bull. They received from 4 to 5 quarts of skim milk as a basal ration daily, and from 1 to 2¼ pounds of calf meal daily as gruel. Calf II. underwent a severe attack of indigestion at the close of the experiment, lost her appetite and became quite emaciated. It was necessary to put her on an entire diet of skim and whole milk for a month in order to restore her to normal condition. The cause of the trouble was not clear.

Lindsey's Calf Meals III. and IV.

Ingredients of III.: —
8 pounds fine corn meal.
10 pounds flour middlings.
14½ pounds flaxseed meal.
10 pounds cheap flour.
7 pounds glucose sugar.
½ pound salt.

Cost, 3.4 cents a pound.

This meal differed from I. in the increase of the glucose sugar, to note if the additional sugar had any ill effect on the nutrition of the calf.

Ingredients of IV.: —
10 pounds fine corn meal.
10 pounds flour middlings.
14½ pounds flaxseed meal.
15 pounds cheap flour.
½ pound salt.

Cost, 3 cents a pound.

This meal differed from the preceding in the removal of the glucose and in the increase of the flour.

Results.

CALF.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Rowen (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Grade Holstein VI.,[1] . .	60	1,584	237	210	$15 24	6.1	251	1.70	148
Grade Ayrshire VII.,[2] .	68	1,670	230	200	14 49	6.5	224	1.50	148

[1] Bull fed calf meal III.

[2] Bull fed calf meal IV.

Both calves did well, and no adverse effect of the glucose was noted in case of Calf VI. The calves each received 5 quarts of skim milk daily

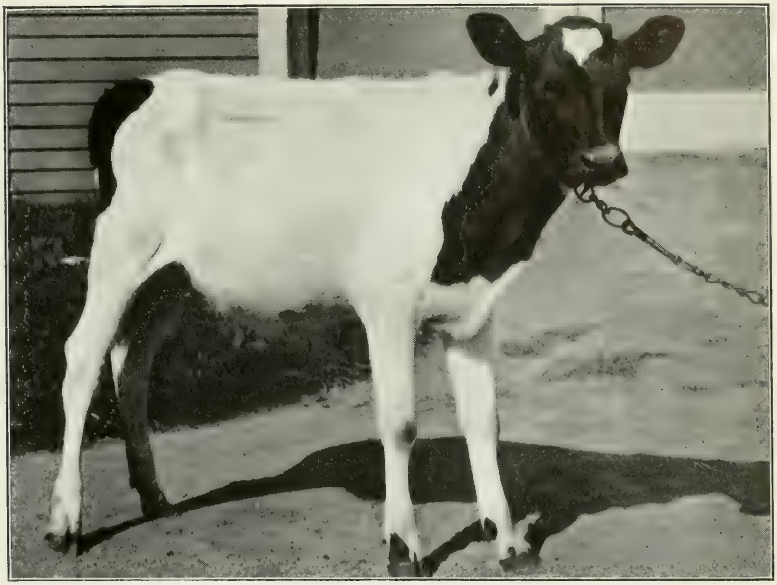

FIG. 5.— White. Lindsey's calf meal I.

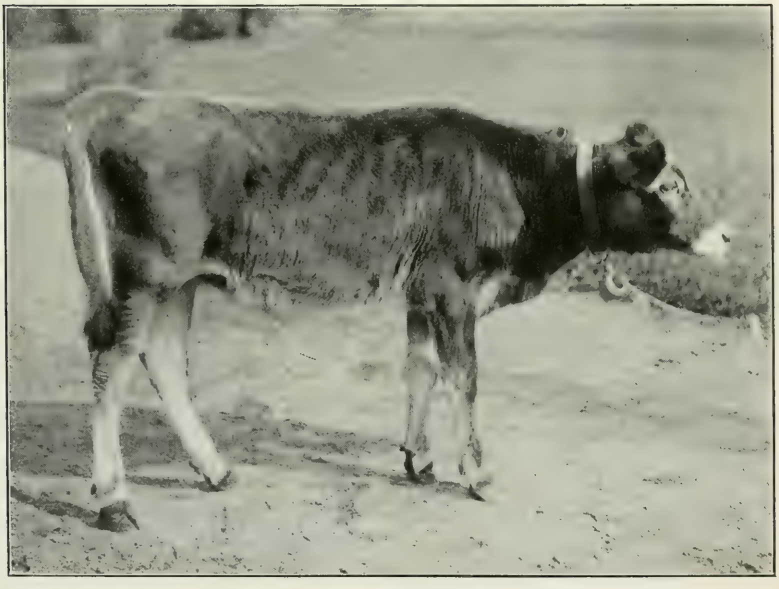

FIG. 6.— Jersey II. Lindsey's calf meal II.

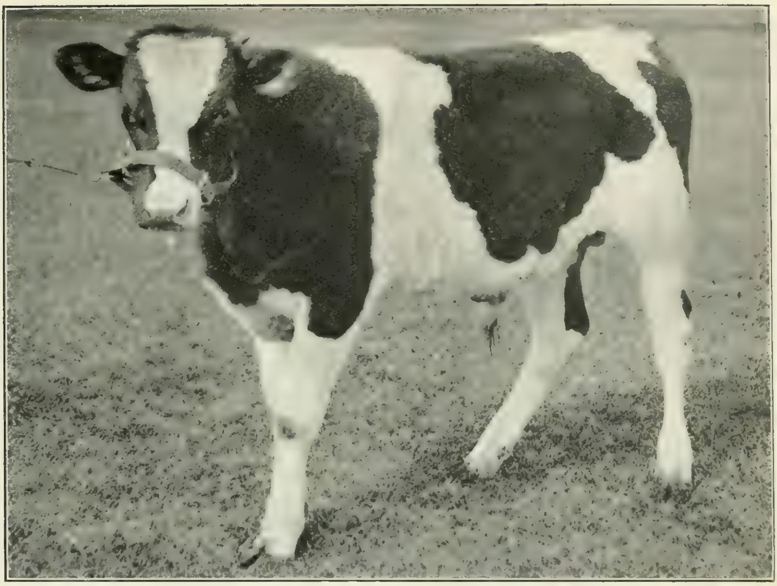

Fig. 7. — Holstein bull. Lindsey's calf meal III.

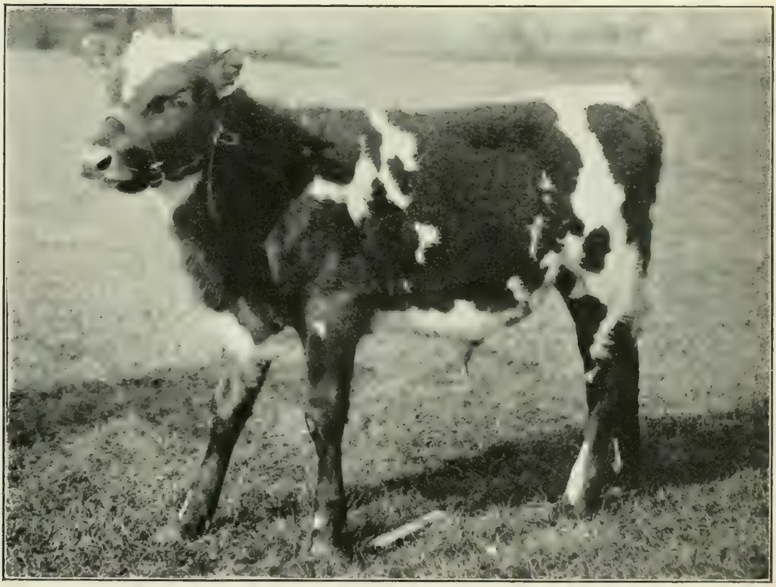

Fig. 8. — Ayrshire bull. Lindsey's calf meal IV.

until they were 120 days old, when the amount was reduced to 3 quarts daily. During the fifth month they received as high as 2½ pounds of calf meal daily as a drink. They were both very vigorous calves, and while they suffered at times from slight attacks of scours, they grew rapidly.

Lindsey's Calf Meal V.

This meal was made so that it contained a fairly liberal amount of ground oat flakes and some flaxseed meal, together with flour middlings and corn meal. The flaxseed, being expensive, was reduced somewhat from the amount used in the other meals, and the blood flour was incorporated as a check to scours.

Ingredients: —

22	pounds ground oat flakes.
10	pounds flaxseed meal.
5	pounds flour middlings.
11	pounds fine corn meal.
1½	pounds prepared blood flour.
½	pound salt.

Cost, 3 cents a pound.

Results.

Calf.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Rowen (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Ida II., ...	52	1,658	219	395	$14 69	7.2	203	1.10	188
Red IV., ...	108	1,440	229	385	15 60	8.3	188	1.20	171
Betty III., ...	128	943	230	401	14 68	7.9	186	1.19	156
Colantha, ...	119	1,229	229	440	15 50	7.1	218	1.50	142

The first two calves were Jerseys, the next a grade Ayrshire, and the last a high-grade Holstein. Ida II. was fed 4 quarts of skim milk and as high as 21 ounces of calf meal daily as gruel. During the last month of the trial she also consumed 1 pound of dry calf meal a day. She was a thrifty calf, and although she suffered from two short attacks of scours, she did well during the entire trial. Red IV. received daily 4 quarts of skim milk and as high as 20 ounces of calf meal in water. She also ate 1 pound of the dry meal daily during the final month. She was not affected with scours and grew steadily. Betty III. received but 3 quarts of skim milk daily after the first two months. She consumed as high as 1½ pounds of moist calf meal daily, and also 1 pound of the dry meal per day for the last month. She was a very thrifty calf. Colantha was given 4 quarts of skim milk each day. She also consumed a maximum of 1¼ pounds of moist calf meal daily and 1½ pounds of dry meal daily for the last month. She was a vigorous calf and was not troubled with scours.

Lindsey's Calf Meal VI.

Ingredients: —
35 pounds ground oat flakes.
12½ pounds barley malt.
1½ pounds blood flour.
½ pound bicarbonate of potash.
½ pound salt.

Cost, 3.3 cents a pound.

The malt is intended as a food and also to act upon the starch in the oats and convert it partly to maltose, in which form the oats are more easily digested. This combination is made after the formula of Liebig,[1] only oat meal is substituted for wheat meal. Our method of preparation was as follows: The malt was kept separate from the other ingredients. Three ounces of the oat meal-blood-potash mixture were converted into a paste with cold water, and then sufficient water added to make 1 quart, and enough prepared at one time for each twenty-four hours. This mixture was cooked or heated very warm for fifteen minutes and then cooled to 100° to 120° F. One ounce of ground malt was then added for each quart of the first mixture, and the latter allowed to stand for one-half hour. It was heated again to near boiling, then cooled and fed milk-warm. The basal ration of skim milk was added just before feeding. The reason for heating to near boiling or to boiling before adding the malt is to gelatinize the starch, which enables the malt to act on it more thoroughly.

Results.

CALF.	Whole Milk (Pounds).	Skim Milk (Pounds).	Calf Meal (Pounds).	Rowen (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).	Total Gain (Pounds).	Daily Gain (Pounds).	Days in Trial.
Samantha III., . . .	113	1,397	191	310	$14 64	7.2	202	1.33	151
Samantha IV., . . .	135	1,357	203	220	14 98	7.7	194	1.22	159
Colantha II., . . .	167	1,361	305	400	19 99	7.8	255	1.50	160

All three were thrifty grade Holsteins. Samantha III. received 4 quarts of skim milk daily and as high as 1½ pounds of calf meal as gruel, and 1 pound of dry meal daily. Samantha IV. received 5, 4 and 3 quarts daily of skim milk as the trial progressed. During the latter part of the

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[1] Kellner's Ernährung, etc., sixth edition, p. 283.

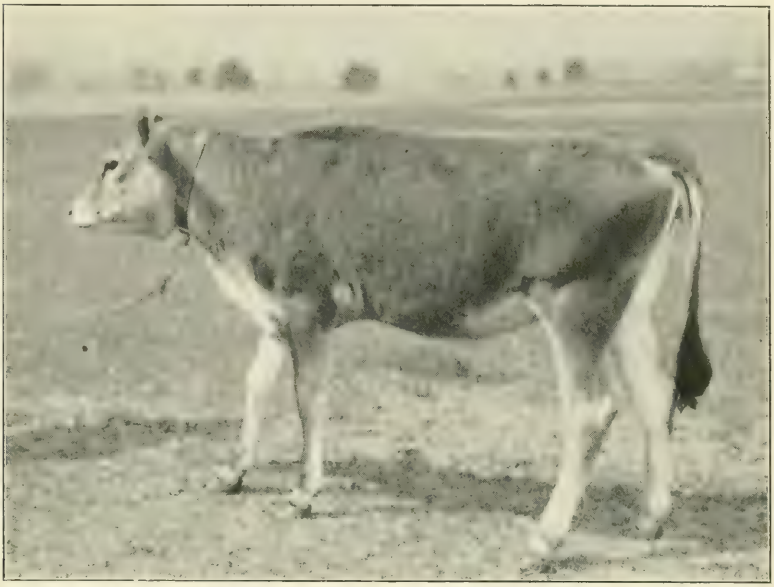

Fig. 9.— Red IV. Lindsey's calf meal V.

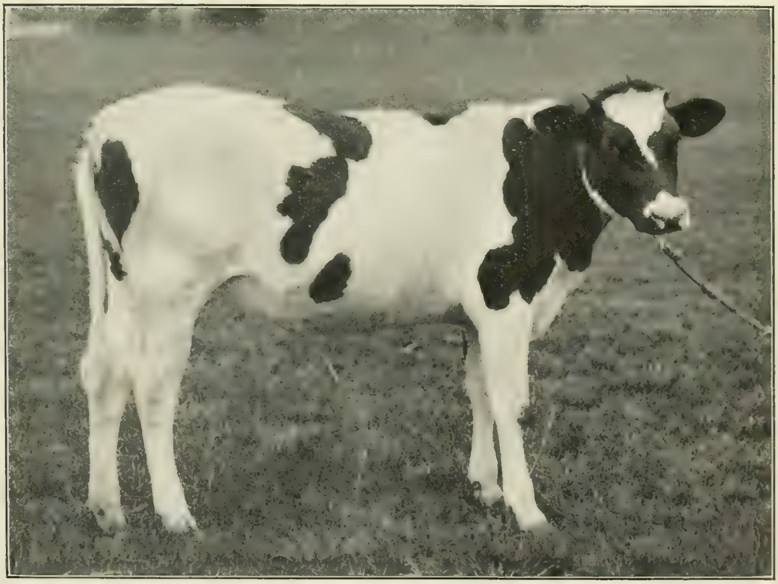

Fig 10.—Samantha III. Lindsey's calf meal VI.

trial she consumed the same amounts of calf meal daily as did Samantha III. Colantha II. received 4 quarts of skim milk daily, as high as $1\frac{1}{2}$ pounds of calf meal as gruel, and the same amount of dry calf meal daily. She was an exceptionally vigorous calf.

Tabular Summary of All Trials.

Kind of Ration.	Number of Calves.	Days in Trial.	Daily Gain (Pounds).	Total Food Cost.	Cost of Food per Pound of Gain (Cents).
Skim milk in large supply, ordinary grains and hay.	10	235	1.22	$22 08	7.7
Skim milk and Hayward's Calf Meal (Lindsey).	2	173	1.23	20 44	9.6
Whole milk and Hayward's Calf Meal (Hayward).	12	102	1.18	11 34	9.6
Skim milk, Schumacher's Calf Meal (Lindsey).	3	150	1.00	12 27	8.2
Whole milk and Schumacher's Calf Meal as per directions (Wing).	10	132	1.19	13 16	8.5
Skim milk and Blatchford's Calf Meal (Lindsey).	1[1]	-	1.15[1]	-	-
Whole milk and Blatchford's Calf Meal (Wing).	4	150	.87	17 37	13.5
Whole and skim milk and Bibby's Cream Equivalent (Lindsey).	3	148	1.21	13 08	7.5
Whole and skim milk and Lindsey's meal I.	2	147	.97	14 54	10.4
Whole and skim milk and Lindsey's meal II.	3	183	1.04	14 68	7.6
Whole and skim milk and Lindsey's meal III.	1	148	1.70	15 24	6.1
Whole and skim milk and Lindsey's meal IV.	1	148	1.50	14 49	6.5
Whole and skim milk and Lindsey's meal V.	4	164	1.25	15 12	7.6
Whole and skim milk and Lindsey's meal VI.	3	157	1.35	16 54	7.6
Average (calf-meal calves), . . .	48	139	1.17	$13 90	9.0

[1] Not included in the average.

COMMENTS ON THE RESULTS.

The above table shows that in case of 10 calves fed during the first 235 days, or 7.8 months, of their lives on a small amount of whole milk, liberal amounts of skim milk, mixtures of ordinary grains and what rowen they would consume, the average food cost was $22.08, the food cost per pound of gain was 7.7 cents, and the average daily gain was 1.22 pounds.

In case of 48 calves fed during the first 139 days, or 4.6 months, of their lives on a little whole milk, together with calf meals, or with a little whole milk, 4 to 5 quarts of skim milk per day, calf meals and what rowen they would eat, the average food cost was $13.90, with variations of from $11.34 to $20.44; the cost of food per pound of gain was 9 cents, with variations of from 6.1 to 13.5 cents; and the average daily gain was 1.17 pounds, with extremes of .87 pound and 1.70 pounds.

These results indicate that calf meals may be purchased or prepared that will take the place of a considerable amount of whole or skim milk and not interfere with the normal growth of the calf. It is doubtful, however, if one will be able to find any article or combination of articles that will completely take the place of milk during the first two or three months of the calf's life. In case of the writer's own observations with different calf meals he did not think it advisable to attempt to rear the calves during the first four months without the use daily of 3 to 5 quarts of skim milk. A too early attempt to accustom the calf to an exclusive diet of calf meal is likely to produce digestive disturbances that may affect the health of the animal in after life. Young calves differ in their ability to take and utilize foods other than milk, and the careful observation and judgment of the feeder are at all times necessary. Holstein and Ayrshire calves are, as a rule, better able to utilize prepared foods than are the Jersey and Guernsey, although we have had no serious trouble in rearing calves of the latter breeds with a minimum of milk.

Our experiments have shown that we have found some proprietary meals, as Schumacher's and Bibby's, satisfactory as partial milk substitutes. Of our own preparations, Nos. V. and VI. have given very good results. Other calf meals on the market not tested by us may also be equally satisfactory. The special characteristics of a satisfactory calf meal will be discussed under the heading of "Composition of Calf Meals."

It is admitted that it is not very convenient for the dairyman rearing a few calves each year to attempt to prepare his own calf meals, especially if it is necessary to send out of town for some of the ingredients. In such cases it is more desirable to purchase the prepared article, providing one is found that will prove satisfactory. Suitable calf meals ought not to exceed 3 cents a pound in price.

How to feed the Young Calf.

Without recommending any preparation in particular, the writer takes this opportunity to outline the method for feeding the young calf in case it is desired to get along with as little milk as possible.

1. Allow the calf to remain with the dam as a rule for two or three days. In case of Jersey or Guernsey calves it may be necessary to shorten the time because of the laxative effect of such milk.

2. The calf should be kept in a *clean* pen and well bedded. Damp, dirty quarters are to be avoided.

3. The pail out of which the calf is fed, as well as all utensils, must be kept clean. This is vital.

4. At the end of the second or third day begin to teach the calf to drink warm whole milk. That with a low fat percentage (4 or less) is preferable to a richer article. From 4 to 6 quarts daily is sufficient for the first two weeks, the amount depending upon the vigor and size of the calf. It is better to feed three times daily during this time, but not necessary.

5. After the first two weeks warm skim milk can gradually be substituted for the whole milk, and in case of vigorous calves, within a week or ten days thereafter the substitution may be completed.

6. At the end of the second, or possibly the third, week (judgment to be used in all cases), a quart of the calf-meal gruel may be added. This substitute is best prepared, in the opinion of the writer, by using $3\frac{1}{2}$ to 4 ounces of meal to each quart of water. The meal is first stirred with a little cold water to get out the lumps and to convert it into a paste. A quart of boiling or very hot water is then added, and the mixture thoroughly stirred and allowed to stand until milk-warm, in which condition it is fed, preferably mixed with the milk. Neither milk nor calf-meal gruels should be fed cold, but milk-warm. The quantity of skim milk can be reduced to 4 quarts daily, and the quantity of calf-meal gruel gradually increased until the animal is receiving 4 to 6 quarts a day of the latter, depending upon its ability to utilize it.

7. At the end of three months the skim milk can be reduced to 3 quarts, or possibly to 2 quarts, daily if necessary. Before this time the animal should be taught to eat the calf meal dry, by placing some of it in a box fastened to the wall, and at first placing a little in its mouth and rubbing the meal upon its nose. Rowen or fine hay should also be placed before the calf in a little rack, and it will soon learn to take it.

8. At the end of four months the skim milk may be entirely withdrawn and a few weeks later the calf-meal gruel, for by this time the animal should be eating considerable dry meal and hay. Naturally, if skim milk is available it is worth while to feed it until the calf is six months of age, it proving very helpful in increasing growth. Feeders wishing to secure large animals frequently feed skim milk until the animal reaches eight months or even twelve months of age; they also defer breeding until the calf is one year, nine months old.

9. After the calf is five months old, if in good condition, the calf meal can be entirely removed and an ordinary grain mixture substituted, consisting, by weight, of one-third ground oats, one-third wheat bran and one-third corn or hominy meal; or wheat middlings may be substituted in the mixture for ground oats. The roughage may consist of one-half to one peck of silage and what rowen or fine hay the animal will clean up. Emphasis is placed upon the fact that absolutely definite rules relative to the time of substituting the different foods cannot be given, so much depending upon the condition of the calf. The close observation and good judgment of the feeder are very necessary if the full measure of success is to be attained.

10. In case of scours, or if the animal begins to show a fickle appetite, the best remedy is to cut down the food supply one-half or even two-thirds in amount. Do not overfeed in any case. The calf should always have an appetite for more than the amount given to it.

11. In case of our own calf-meal preparations, Nos. V. and VI. are to be preferred. For the preparation of VI. see special instructions on page 60.

THE CHEMICAL COMPOSITION OF MILK AND CALF MEALS.

The following tables show the relative proportion of the several chemical groups in calf meals as compared with whole and skim milk, the latter with their natural water content, and also reduced to a 10 per cent. water basis for easier comparison with the various calf meals: —

(*a*) *Milk.*

	Water.	Ash.	Fiber.	Protein.	Extract Matter.	Fat.
Natural milk,	87.5	.70	–	3.30	4.80[1]	3.70
Milk on 10 per cent. water basis,	10.0	5.00	–	23.76	34.56[1]	26.64
Skim milk, deep-setting process,	90.8	.70	–	3.30	4.88[1]	.32
Skim milk on 10 per cent. water basis,	10.0	6.85	–	32.28	47.78[1]	3.13

(*b*) *Calf Meals in Trials.*

Hayward's,[2]	–	–	–	–	–	–
Schumacher's,	9.34	2.22	1.52	17.15	62.29	7.48
Blatchford's,	10.42	5.13	6.03	24.91	48.56	4.95
Bibby's,	7.99	6.23	4.90	16.78	49.68	14.42
Lindsey's, I.,	7.37	3.30	2.78	14.98	58.99	12.58
Lindsey's, II.,	7.34	3.50	2.93	20.89	56.34	9.00
Lindsey's, V.,	6.84	3.55	2.34	17.08	57.64	12.55
Lindsey's, VI.,	7.34	3.50	2.14	16.29	65.27	5.46

(*c*) *Other Calf Meals.*

Clover Leaf Calf Meal,	10.78	4.43	5.55	25.31	48.53	5.40
Ryde's Cream Calf Meal,	11.30	4.67	4.50	23.82	51.03	4.68
Sugarota,	10.33	4.36	3.72	25.35	50.51	5.73

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[1] Milk sugar.

[2] Not analyzed.

Reduced to a 10 per cent. water basis, it will be noted that whole milk contains nearly 24 per cent. nitrogenous matter (protein), some 26 to 27 per cent. fat, and over 30 per cent. milk sugar. Skim milk on the same basis contains over 30 per cent. protein, nearly 50 per cent. sugar and a little over 3 per cent. fat.

Many of the various calf meals are made, so far as the relative proportions of the several ingredients are concerned, to imitate dry skim milk. Thus Blatchford's Calf Meal contains 24 or more per cent. of protein, 48 per cent. of extract matter and about 5 per cent. of fat. The Bibby meal, on the other hand, contains noticeably less protein and considerably more fat. The calf meals prepared by this station contained from 15 to 20 per cent. of protein and from 5 to 12 per cent. of fat. All of the meals, with the possible exception of Bibby's, contained noticeably less ash than that contained in the skim milk, and most of them too much fiber. It is believed that the fiber content should be kept at a minimum, *i.e.*, not over 3 per cent.

In our own case we have refrained from making a mixture with over 20 per cent. protein, for the reason that it was feared the calf would find difficulty in caring for a larger amount. It must be remembered that the protein of milk exists in solution as casein and lactalbumin, — easily digested and assimilated forms of nitrogen, — while the protein in the different grains is in forms not so easily utilized by the young animal. The writer sees no objection to a meal containing 12 per cent. of fat, providing it can be economically incorporated. The high price of flaxseed meal, the usual source of fat, renders its use in very large amounts of doubtful economy. It is probable that a higher ash percentage than 3 per cent. may prove helpful, but it would have to be made artificially and incorporated, as most of the grains employed do not contain more than that percentage. If a minimum of 3 to 4 quarts of skim milk is fed each day for the first three months, the 3 per cent. of ash in the calf meal would probably prove sufficient.

In preparing a calf meal the object should be to use only those ingredients that are easily and highly digestible, and at the same time are not too expensive. Among such feeds may be mentioned finely ground corn meal, flour middlings, ground rice, wheat flour, oat flakes, barley malt, cocoanut meal and flaxseed meal. Cottonseed meal in any quantity is not advised; oat flakes and malted grains seem to be quite satisfactory. Dry skim milk is a valuable substance, but its cost is likely to prevent its use. It is doubtful if aromatics such as fenugreek and anise are of any special value. The use of carob bean meal (St. John's-bread) imparts a sweet taste to the calf meal. Its value as compared with its cost is unknown to the writer.

PART II.

THE COST OF REARING A DAIRY COW.

FOOD COST.

As explained in the first part of this bulletin, the station for the past ten or more years has made a practice of raising its own dairy stock. It is intended in what follows to show the complete food cost of the heifer from the time it was dropped until it reached the age of two years. The labor and other costs are also quoted from an authentic source.

Some of the calves, until they were six to eight months of age, were developed on skim milk, grain and hay, while others received small amounts of whole milk, 4 to 5 quarts daily of skim milk, calf meal and hay. The calves were usually dropped in the autumn, and fed as previously outlined until May, when they were sent to pasture, and returned to the feeding barn some time in October. During the late autumn, winter and early spring they were given such roughage as corn fodder, one peck to one-half bushel of silage daily if the same was available, and what hay they would eat. In case silage was not on hand rowen or fine hay was supplied, care being taken to give no more daily than would be fully consumed. They were fed also 2 to 3 pounds of a grain mixture daily, composed, by weight, of one-third wheat bran, one-third corn or hominy meal or wheat middlings, and one-third gluten feed; or one-fourth wheat bran, one-half corn or hominy meal, and one-fourth cottonseed meal. In some cases other grain mixtures were supplied, depending upon cost and availability. They were usually bred when fifteen to twenty months of age, sent to pasture a second summer, and, on return, fed as previously indicated, excepting that if not at pasture the grain ration was increased in amount, in some instances, to 5 pounds daily during the last three or four months previous to calving, in order to bring them into good physical condition and to aid in the development of the milk glands. During the winter months they were carded daily, and usually turned into the barnyard for a number of hours each day in pleasant weather. Here follows a tabulated statement of the food cost. In the table P. B. means pure bred, G. means grade, A. H. J. and G. mean Ayrshire, Holstein, Jersey and Guernsey, respectively. It might be added that the station herd has consisted mostly of grade Jerseys, with a few pure breds, although of late some grade Holsteins and a number of grade Ayrshires have been added. The herd has been kept for the purpose of studying the nutritive effect of different feeds and feed combinations upon the production and cost of milk, and not maintained as a herd for economic dairying. At the same time, it has been our object to keep only profitable milk producers. The grade cows were bred to pure-bred bulls, and only those heifers raised which gave promise of developing into satisfactory dairy cows. In making the following tabulation the costs of the various feeds were: hay $10, silage $4.50, green feed $3.50 and grain mixtures $32 a ton. The value placed upon the milk and calf meal was the same as stated in the first part of this bulletin. Pasturage was charged at 25 cents a week for the first summer, and 30 cents for the second summer. In a few cases the animals, for some reason, did not go to pasture for one summer, but were soiled, which resulted in a higher food cost. The hay was charged at a price approximating cost, rather than at market value. For the sake of comparison it was thought best to determine the food cost at two years of age in each case, rather than at time of calving which, of course, varied. The calves were raised in different years, and primarily to keep up the herd, hence in some cases, especially if the animals were at pasture, we did not have the live weight when the animals were exactly two years old.

NAME.	Breed.	Weight when Two Years Old (Pounds).	Total Gain (Pounds).	Daily Gain (Pounds).	Cost of Feed (Dollars).	Cost of Feed per Pound Gain (Cents).
Maud,	G. G.	780[1]	710	.88	61.80	–
Amy of W.,	P. B. J.	635[2]	575	.73	49.71	–
O. Amy,	P. B. J.	–	–	–	56.23	–
Betty,	G. J.	730	670	.92	60.05	8.96
Red III.,	G. J.	680	615	.84	56.02	9.11
Susie,	G. J.	650[3]	600	.74	78.79[3]	–
Lena,	G. J.	–	–	–	55.75	–
Mibbs,	G. J.	725[4]	665	.84	68.81	–
Daisy II.,	G. J.	675	620	.85	49.54	7.99
Ida,	P. B. J.	735[5]	–	–	53.32	–
White,	G. H.	900[6]	815	1.04	65.25	–
Amy II.,	P. B. J.	600[7]	555	.72	46.84	–
Fancy III.,	G. J.	683	623	.85	54.85	8.80
Samantha II.,	G. H.	900[8]	820	.93	58.03	–
Betty II.,	G. A.	745	685	.94	58.98[9]	8.61
Betty III.,	G. A.	725[10]	655	.91	48.44	–
Ida II.,	P. B. J.	746	689	.94	53.78	7.81
Cecile II.,	P. B. J.	600	557	.76	58.89	10.57
Samantha III.,	G. H.	–	–	–	63.07	–
Red IV.,	G. J.	615[11]	542	.88	56.42	–
Average,	–	713	–	.86	57.73	–

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[1] Eight hundred five days.

[2] Seven hundred eighty-six days.

[3] Eight hundred thirteen days. High cost due to soiling one season.

[4] Seven hundred ninety days.

[5] Eight hundred fifty-seven days. Calf purchased when three months old; food record for two years from date of purchase.

[6] Seven hundred eighty-two days.

[7] Seven hundred seventy days.

[8] Eight hundred eighty-four days.

[9] High cost due to soiling one season.

[10] Seven hundred sixteen days.

[11] Six hundred eighteen days, last weight.

It will be seen that the animals, most of which were grade Jerseys, varied in live weight from 600 to 900 pounds, the latter being the weight of a thrifty grade Holstein heifer. The average weight was 713 pounds, and the daily average gain .86, or a little less than a pound a day for the first two years.

The food cost varied from $46.84 to $78.79, the latter cost being due to the fact that the heifer was soiled one season. The food cost of two thrifty grade Holstein heifers was $58.03 and $63.07, respectively, and the average cost of the 20 heifers was $57.73.

Several of the heifers did not prove satisfactory and were disposed of; for instance, Maud and Mibbs were poor producers, O. Amy and Lena failed to breed, Susie developed tuberculosis, and Daisy II. aborted. The prices secured for these discards are, unfortunately, not available, but a fair estimate would be about $140, which, deducted from the total food cost of the 20, — $1,154.57, — would leave $1,014.57, this sum being the cost of the 14 good ones remaining, or an average cost of $72.47. The discarding of 30 per cent. of the 20 heifers raised seems large, and it is doubtful if it would hold true in most cases. The results, however, are presented as secured. It is known that in spite of the best judgment in the rearing of dairy animals a considerable loss is experienced through one cause or another.

Trueman,[1] in a detailed feeding record of one Guernsey, two Jersey and two Holstein heifers, shows that the average food cost of each heifer at two years of age was $55.[2] He calls attention to the fact that "a certain number will fail to be good producers, and will have to be discarded at a loss," but presents no data on this subject.

Morse [3] in 1898 has shown that the food cost of raising dairy heifers to sixteen months of age averaged $28.81 each. This, however, was at a time when the cost of feed was very much less than at present.

Bennett[4] and Cooper[4] present exceedingly interesting data on the entire subject in a publication entitled, "The Cost of Raising a Dairy Cow." They co-operated with C. I. Brigham on his private farm located in Wisconsin. The dairy farm contained 50 Jersey cows and about 40 head of young stock. The observations covered a period of five years, during which time 117 calves, some of which were bulls, were under observation. The average food cost of the 73 heifers that reached maturity was $40.83, the cost of the different articles of feed being below that charged in our own experiment.[5] As nearly as can be ascertained from the bulletin, of the 86 *heifer* calves on trial during the five years, 73 were brought to maturity, 2 died and 11 were discarded, a loss of 15.1 per cent.

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[1] Bul. 63, Storrs Exp. Sta.

[2] Whole milk $2 and skim milk 25 cents a hundred pounds; hay $12, silage $4, and grain $30 a ton; pasture $2 and $4 a season.

[3] Bul. 58, N. H. Exp. Sta.

[4] Bul. 49, U. S. Department of Agriculture, 1914.

[5] Whole milk $1.50 to $1.60 a hundred; skim milk 20 cents a hundred; bran and corn $22 to $25, oats and barley $25, linseed meal $35 to $41, hay $8 to $10, alfalfa $12 to $15, corn stover $4, silage $4 per ton; pasture 10 to 20 cents a week.

OTHER COSTS.

Because of our method of raising the calves (a few each year), it was not possible to get at the other items entering into the total cost of the two-year-old heifers. Trueman makes an estimate, while Bennett and Cooper are able to present exact data, of which the following is a summary: —

Cost (Other than Food) of Two-year-old Heifer.

	Bennett and Cooper.	Trueman (estimated).
Labor,	$8 00	$10 00
Interest on value of heifer,	3 65	–
Interest on buildings,	2 38	–
Interest on equipment,	55	–
Bedding,	3 00	2 00
General expense,	2 93	4 00
	$20 51	$16 00

The man labor was charged on the Brigham farm at 12 cents, and the horse labor at 10 cents, an hour; interest on the value of the heifer during the first and second years at 5 per cent., interest and depreciation on the barn at 8 per cent., interest and depreciation on equipment, such as steam boilers for heating milk, feeding pails, cans and the like, 20 per cent. The term "general expense," as used by Bennett and Cooper, was meant to include a general overhead expense of the entire farm business, which on the Brigham farm was 5 per cent. of the located expense. The manure from the calf for the two years was assumed to be worth $8 on the Bennett farm and $5 by Trueman. The former assumes, therefore. that the cost of labor is offset by the value of the manure. It would seem to the writer that the labor cost, and probably the interest and depreciation on buildings, would be somewhat greater in Massachusetts than is allowed in Wisconsin.

INITIAL VALUE OF HEIFER.

The Brigham farm considered the initial value of its pure-bred heifer calves to be $7. In our own case we should think that $4 would be near the average value of grade dairy heifers when dropped. Putting the figures available together, we have the following: —

Total Cost of the Two-year-old Heifer.

	Bennett and Cooper (Wisconsin).	Trueman (Connecticut).	Lindsey (Massachusetts).
Initial value of heifer,	$7 00	$4 00[1]	$4 00
Food cost,	40 83	55 00	57 73
Other costs,	20 51	16 00	20 51
Total,	$68 34	$75 00	$82 24
Credit by manure,	8 00	5 00	8 00
Total net cost,	$60 34	$70 00	$74 24

[1] Added by Lindsey.

The writer has adopted the Wisconsin "overhead charge" because it is the best available, and because it is based on careful observations. If anything, it is below rather than above the actual cost in Massachusetts. These "other costs" and "overhead charge" do not include the loss or shrinkage due to death, disease and poor milking qualities of heifers in the process of raising or on arriving at the milking stage. In raising 20 heifers we discarded 6, or 30 per cent., which was probably above the average loss. On the Brigham farm 15 per cent. were discarded during the two years of growth, but, owing to fortunate methods of disposing of them, the loss on the 73 head remaining prorated only 42 cents a head, which was exceedingly small. Our cash loss per head on the 14 heifers remaining on the basis of food cost was $14.53, due partly to the fact that the animals had reached the age of two or more years before the discard was made.

The sum of $10 per head, in the judgment of the writer, would not be an excessive average figure to allow for loss due to discarding in the rearing of dairy heifers until they come into milk. In some cases the loss may be greater, while in other cases scarcely anything, but in a series of years a noticeable shrinkage is bound to occur. Adding this to our net cost of $74.24 brings the amount to $84.24 as the total cost of raising an average heifer weighing 713 pounds to two years of age. If this figure seems exceedingly high to many they should consider the various data given, and note in what particulars they think the charges excessive.

All things considered, the writer is of the opinion that $75 to $85 represents the cost of raising the average dairy heifer until she reaches the age of two years.

Trueman, as a result of his observations, states: —

> Considering all these factors (feed, labor, interest, taxes, barn room, discarding, etc.), it is doubtful if good heifers can be raised and put to work in the herd for much under $80 each. Good heifers are not dear at that price, however. They are young and vigorous and ready for a long life of usefulness, and are cheaper at that price than the average cows bought at maturity for $60.

Bennett and Cooper say that the "cost of producing a dairy heifer seems to indicate that a heifer entering the dairy herd at two years of age must be worth at least $60 to cover cost only.[1] It would appear that a farmer cannot afford to raise a heifer calf that will not sell for more than $60 at two years of age."

Concluding Suggestions.

1. The above data make it very clear that too much care cannot be used in the selecting of heifer calves for dairy cows. They should be sired by bulls of known reputation and be dropped by large producing cows. Heifers from unknown bulls or from inferior cows are not worth the raising.

2. As small an amount of milk should be used as is consistent with a satisfactory growth of the calf, because of the relatively high cost of both whole and skim milk. Of the total food cost, in case of our own experiments, milk represented from 11 to 35 per cent., with an average of 20.5 per cent. In case of the Wisconsin trials milk represented one-third of the total food cost.

3. Calf meal will serve as a partial milk substitute, but at 3 cents a pound, the 3½ ounces necessary to make a quart of the substitute cost two-thirds of a cent, and at that figure the skim milk is to be preferred; hence, if skim milk can be had at not over two-thirds to three-fourths of a cent a quart, it is to be preferred to calf meal at 3 cents a pound.

4. The calves should be pastured for two seasons whenever possible, and the pasture should not be overstocked. It frequently happens that owing to overstocking or to dry weather the young animals make but little growth during the pasture season, and it requires several months of barn feeding to bring them into a thrifty growing condition.

5. It is rarely advisable to leave the animals in the pasture after October 15. In case of early hard frosts it is better to bring them in October 1.

6. During the remainder of the year the most economical feeds are likely to be silage, early cut hay, possibly some cut corn stover, and 2 to 3 pounds daily of a standard grain mixture. The grain may be increased to 5 pounds daily three or four months before calving, whenever practicable, in order to aid in developing the milking qualities of the future cow.

7. An effort should be made to provide low-cost but comfortable winter quarters, dry and clean surroundings and convenient arrangements in order to keep the labor cost at a minimum.

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[1] The food cost of the Wisconsin heifers, due primarily to the less cost of many feeds during the experiment, was some $16 less than the Massachusetts cost. If this extra cost was added to the $60, it would bring the total up to $76, not including loss through discards.

BULLETIN No. 165 NOVEMBER, 1915

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION.

THE EFFECT OF SULFATE OF AMMONIA ON SOIL.

By R. W. Ruprecht and F. W. Morse.

This bulletin is a record of efforts to determine the changes which have been produced in a soil by years of continuous use of sulfate of ammonia as a fertilizer. Treatment of soils with solutions of the sulfate of ammonia, and analyses of the drainage waters from the fertilizer plots, show that sulfate of calcium is readily formed and removed when lime is present, while after the exhaustion of the lime there is the formation of salts of iron and aluminium. Culture studies with seedling plants and solutions of iron sulfate and of alum show injurious action of the salts on the roots.

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[1] On account of ill health not in administrative charge.

[2] In administrative charge.

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APPROVED BY THE STATE BOARD OF PUBLICATION.

THE EFFECT OF SULFATE OF AMMONIA ON SOIL.

R. W. RUPRECHT AND F. W. MORSE.

INTRODUCTION.

This bulletin is a record of efforts to determine the changes which the long-continued use of sulfate of ammonia has produced in soils.

The action of ammonium sulfate on soils has received attention in one way or another for many years. Among the first workers who used this salt in experiments was Way[1] (1850). In studying the absorption of ammonia by soils he found that soils had the power to absorb the ammonia from ammonium sulfate, but left the acid radical in solution in combination with another base, generally calcium. Voelcker[2] continued the work of Way and confirmed his results. Beyer,[3] in studying the absorption with potassium and ammonium chlorides, found that the absorption was dependent on the amount of iron and aluminium oxides present in the soils, and that the quantity of calcium and magnesium removed was almost equivalent to the potassium absorbed. Morse and Curry,[4] in working on clay with potassium and sodium salts, found that the bases were absorbed, and that in exchange calcium, magnesium, iron and aluminium were removed. In the presence of lime and carbonate of lime the iron and aluminium were precipitated.

Other workers[5] who studied the absorption but used different salts found the same general principle to hold true, namely, that the soil has the power to absorb the basic part of the salt, but that this power does not extend to the acid radical.

As to the results due to fertilization with ammonium sulfate we may cite the following investigators: —

Lawes and Gilbert,[6] in studying the drainage waters from differently fertilized plots, found that the plots treated with ammonium sulfate had much larger amounts of calcium removed than the other plots. They reached the conclusion that all of the sulfuric acid from the ammonium sulfate was removed as calcium sulfate. Wheeler[7] found that the long-continued use of ammonium sulfate brought the soils into an acid condition which could be corrected by liming. Hall and Miller[1] found that when ammonium salts were used as a fertilizer the loss of calcium carbonate was equivalent to the acid of the ammonium salt used. Nitrate of soda and manure diminished this loss of calcium. Hall and Gimingham[2] state that the continuous application of ammonium salts brought soils into an acid condition, and that the reaction was a double decomposition between calcium humate and the ammonium salts. In a later publication Hall[3] states that the acidity was caused by micro-fungi in the soil, which split up the ammonium sulfate to obtain the ammonia, thereby setting free sulfuric acid. Hunt[4] found that an acid condition, proving especially harmful to corn and clover, resulted from the continued application of ammonium sulfate.

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[1] Way, Jour. Roy. Agr. Soc., Vol. 11 (1850) and Vol. 13 (1852).

[2] Voelcker, Jour. Roy. Agr. Soc., Vols. 21, 60 and 62.

[3] Beyer, Ann. der Landwirtschaft, Bd. I. and II.

[4] Rept., N. H. Agr. Exp. Sta., 1906–08, p. 274.

[5] Frank, Salomon, Biedermann, Neutler, Knop, Frey, Pillitz, Kellner and Van Bemmelen.

[6] Lawes and Gilbert, Rothamstead Memoirs, Vol. 5, p. 97.

[7] Wheeler, Ann. Rept., R. I. Exp. Sta., 1893.

The conditions produced by the continuous application of ammonium sulfate on crops, as reported by these investigators, are very similar to the conditions on the nitrogen field at this experiment station.

SOIL USED IN THE EXPERIMENTS.

The soil used for the various experiments herein described was taken from one of the oldest fields on the station farm. A record of this field has been kept for thirty-three consecutive years, and in that time it has received only chemical fertilizers. Since 1890, when the present scheme of fertilizing was inaugurated, the field has been used to compare different forms of nitrogen fertilizers. The plots are one-tenth acre in area and have a 2-inch tile drain running through the center of each plot at an average depth of 3 feet.

The chemicals applied since 1890 to the plots studied have been as follows: —

TABLE I. — *Chemicals applied annually.*

Plot 0.	Manure, dissolved bone black, sulfates of potash and magnesia.
Plot 1.	Nitrate of soda, dissolved bone black, muriate of potash.
Plot 5.	Sulfate of ammonia, dissolved bone black, sulfates of potash and magnesia.
Plot 6.	Sulfate of ammonia, dissolved bone black, muriate of potash.
Plot 7.	No nitrogen, dissolved bone black, muriate of potash.
Plot 8.	Sulfate of ammonia, dissolved bone black, muriate of potash.

The amounts applied have been 45 pounds of nitrogen per acre in nitrate of soda, sulfate of ammonia or manure, 80 pounds of phosphoric acid per acre in dissolved bone black, and 125 pounds of potash per acre in muriate of potash or double sulfates of potash and magnesia. On plot 0 the phosphoric acid and potash naturally present in the manure have been supplemented by enough chemicals to make 80 pounds of phosphoric acid and

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[1] Hall and Miller, Proc. Roy. Soc., Ser. B 77, No. B 514.

[2] Hall and Gimingham, Jour. Chem. Soc., Vol. 91 (1907), No. 534.

[3] Hall, Jour. Roy. Agr. Soc., 70 (1909), p. 12.

[4] Hunt, Bul. 90, Penn. State Exp. Sta.

125 pounds of potash. The only organic matter added has been in the form of crop residues and catch crops plowed under. Hydrated lime was applied to one-half of the field at the rate of 3,000 pounds per acre in 1909, and again in 1913, when the rate of application was 4,000 pounds. The application was made crosswise of the plots so that every plot was half limed and half unlimed.

The first soil samples were taken from these plots in 1912, just before the fertilizers were applied and after the land had been plowed. The second set of samples was taken in the spring of 1913, immediately after the lime had been applied and harrowed in, but before the application of any fertilizers. The soils were taken to the laboratory as soon as sampled, thoroughly mixed and air-dried. In subsampling, the soil was passed through a sieve having seven holes to the linear inch. No finer sieve was used, as it was desired to have the soil in as nearly actual field condition as possible.

The crops grown in the years previous to the sampling (1911 and 1912) were corn with clover sown in the corn during the fall. The crops were the same both years, as the clover made a poor catch in 1911 and was plowed under.

Method of Investigation.

A large part of the investigation was carried on with different strengths of ammonium-sulfate solutions. The four strengths used most were one-tenth normal (N/10), normal (N), two and one-half times normal (2½ N) and five times normal (5 N).

Unless otherwise stated the soil was treated as follows: 150 grams of air-dried soil were treated with 750 cubic centimeters of the ammonium-sulfate solution. The mixture was allowed to stand, with frequent shakings, for two hours, and then filtered through an unwashed filter paper. In every case the filtrate was perfectly clear but yellow, the intensity of the color varying between the limed and unlimed soils and with the strength of the solution used. The solutions were all neutral to litmus and phenolphthalein.

The solutions were analyzed for the amount of ammonia absorbed, and for the iron and aluminium, calcium, sodium, potassium, sulfates, chlorides and nitrates removed.

Absorption of Ammonia.

The ammonia was determined by the magnesium oxide method.[1] From 1 to 10 cubic centimeters of the solutions were used for a determination, depending on the concentration of the solution. Table II. gives the amounts in milligrams of the ammonia absorbed by 100 grams of air-dried soil.

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[1] Bul. 107, Bureau of Chem., p. 9, 1910 edition.

TABLE II. — *Milligrams of Ammonia absorbed from Ammonium-sulfate Solutions by 100 Grams of Air-dried Soil.*

[0 L = plot 0, limed end; 0 UL = plot 0, unlimed end, etc.]

PLOT.	N/10 Solution.	N Solution.	2½ N Solution.
0 L,	72.5	212.5	–
0 UL,	60.0	162.5	175
1 L,	72.5	162.5	250
1 UL,	60.0	200.0	275
6 L,	77.5	187.5	175
6 UL,	42.5	62.5	100
7 L,	62.5	200.0	100
7 UL,	57.5	125.0	225
8 L,	67.5	150.0	150
8 UL,	42.5	87.5	235

Taking the plots as a whole we find that with an increase in the concentration of the ammonium-sulfate solution used the amount of absorbed ammonia increases. Comparing the amounts of ammonia absorbed by soil from the different plots we find that the unlimed ends of plots 6 and 8 consistently show a smaller absorption than any of the others, except in one case with the strongest solution by soil from plot 8. The variations in amounts absorbed on the remaining plots are within the limits of possible error, on account of the concentration of the solutions employed.

ABSORPTION OF DYES.

This difference in the absorption capacity of the different plots is less strikingly shown by a study of the dye absorption. The dyes used were aniline blue, aniline green, corraline and eosine. The method of procedure was as follows: 10 grams of soil were shaken up with 100 cubic centimeters of the dye and then set aside until the supernatant liquid was clear. Fifty cubic centimeters were then pipetted off and compared with a standard dye solution in a colorimeter.

The eosine and corraline were not absorbed by the soil in a measurable quantity, if at all. One hundred cubic centimeters of the aniline blue and aniline green in concentrations below 50 parts per million were entirely decolorized by 10 grams of soil. The concentrations used were 50 and 100 parts per million.

TABLE III. — *Dye absorbed by 10 Grams of Soil from 100 Cubic Centimeters of Dye Solution.*

Plot.	Aniline Blue (50 Parts per Million).	Aniline Blue (100 Parts per Million).	Aniline Green (100 Parts per Million).
0 L,	49.68	98.45	97.00
0 UL,	49.71	98.50	95.00
1 L,	–	99.12	96.67
1 UL,	49.76	98.94	95.97
6 L,	49.73	98.58	95.30
6 UL,	49.33	93.54	87.50
7 L,	49.74	98.40	96.00
7 UL,	49.69	98.24	94.75
8 L,	49.73	98.61	94.50
8 UL,	–	97.76	92.00

The table shows that the unlimed ends of plots 6 and 8 absorb a little less dye than do the limed ends or the other unlimed ends. While the other plots also show a higher absorption in the limed than in the unlimed ends the differences are smaller.

The dyes seem to have a deflocculating effect on the clay in the soil, as they settle much more slowly than with a corresponding water treatment. This is particularly noticeable on the limed end of plot 1, from which the solution, even at the end of twenty-four hours, was too turbid to be used in a colorimeter.

CALCIUM OXIDE REMOVED.

Calcium oxide was determined by the titration method with potassium permanganate. The amounts removed from 100 grams of air-dried soil are shown in Table IV.

TABLE IV. — *Milligrams of Calcium Oxide removed from 100 Grams Air-dried Soil by Distilled Water and by Different Solutions of Ammonium Sulfate.*

Plot.	1912.				1913.			
	Water.	N Solution.	2½ N Solution.	5 N Solution.	Water.	N/10 Solution.	N Solution.	2½ N Solution.
0 L,	–	–	–	–	12.26	103.75	218.05	257.30
0 UL,	–	–	–	–	7.04	61.98	108.45	116.55
1 L,	69.45	176.05	182.65	171.00	10.95	95.65	205.15	242.85
1 UL,	6.66	106.95	117.80	124.60	6.91	61.30	116.65	120.60
6 L,	12.73	116.75	118.05	105.50	11.21	82.19	156.65	184.90
6 UL,	8.42	36.47	42.08	53.90	7.82	18.19	27.11	25.26
7 L,	10.17	177.05	178.70	175.50	10.43	99.03	205.17	243.87
7 UL,	8.42	78.20	83.90	77.50	6.78	43.12	70.25	71.41
8 L,	11.92	122.05	131.10	106.50	9.91	92.95	199.05	233.66
8 UL,	8.77	58.20	59.60	65.85	8.21	37.05	60.10	60.63

Considering the table as a whole we find that more calcium is removed from the limed ends than from the unlimed. The effect of the application of lime in 1913 is plainly shown by the increased amount of calcium removed from the limed ends in 1913 over 1912 by the normal and 2½ normal solutions. Further, in 1912 no increase is noted in the amount of calcium removed from the limed plots with an increase in the concentration of ammonium-sulfate solution used. In 1913, however, an increase is noticed with each increase in the concentration of the ammonium-sulfate solution. With the unlimed ends of the plots no such increase is noticed either year, except between the one-tenth normal and normal concentrations.

Studying the variations between the different plots we find the chief difference to be the smaller amount of calcium removed from the two sulfate plots 6 and 8, both limed and unlimed ends.

In the light of results already reported by other investigators as to the action of ammonium sulfate on calcium in the soils, the foregoing results indicate that ammonia replaces calcium in the soil, the amount varying with the concentration of the ammonium sulfate used and the amount of available calcium in the soil. The smaller amount of calcium removed from the two ammonium-sulfate plots indicates that the previous fertilization with ammonium sulfate has depleted the soil of this element. That sodium nitrate has had a protective action on the calcium in the soil is shown by the larger amount of calcium removed from the unlimed end of the nitrate plot 1 than from the no-nitrogen plot 7. The presence of the soda has prevented the soil from becoming poor in calcium. When larger quantities of lime are present, and the concentration of the ammonium-sulfate solution is high, the protective action largely disappears, as is shown by the amount of calcium removed from the limed end of plot 1 in comparison with plot 7.

Sodium and Potassium removed.

Owing to the large mass of ammonium sulfate and the small amount of sodium and potassium in solution it was difficult to make exact determinations of these elements. Several methods were studied, but the method of weighing the sodium and potassium as the double chlorides, and then determining the potassium as the chlorplatinate was finally adopted. The results obtained are as accurate as could be expected under the circumstances.

TABLE V. — *Milligrams of Sodium Oxide removed from 100 Grams of Air-dried Soil by Different Solutions of Ammonium Sulfate.*

PLOT.	N/10 Solution.	N Solution.	2½ N Solution.
0 L,	13.25	32.60	–
0 UL,	11.40	20.40	25.45
1 L,	14.05	–	23.05
1 UL,	13.50	20.40	22.55
6 L,	7.95	17.75	21.20
6 UL,	9.80	–	18.85
7 L,	9.55	19.90	22.00
7 UL,	10.10	18.30	24.40
8 L,	8.75	19.90	22.00
8 UL,	8.20	–	18.75

Milligrams of Potassium Oxide removed from 100 Grams of Air-dried Soil.

PLOT.	N/10 Solution.	N Solution.	2½ N Solution.
0 L,	12.00	13.60	–
0 UL,	10.75	27.15	20.85
1 L,	15.45	–	27.15
1 UL,	10.75	23.70	23.05
6 L,	10.00	21.50	24.95
6 UL,	12.65	–	21.50
7 L,	17.70	31.25	28.75
7 UL,	13.90	26.85	29.05
8 L,	14.55	26.20	25.25
8 UL,	11.70	–	22.75

As with the calcium the sodium and potassium removed increase with the concentration of the ammonium-sulfate solutions used. Unlike the calcium there are no marked differences in the amounts removed from the limed and unlimed ends of the plots, or from the different plots. This would seem to indicate that the continued use of ammonium sulfate has not diminished the amount of sodium and potassium in the soils, or, stated differently, the absence of lime has not increased the rate at which they were removed from the soils.

In determining the acids in the ammonium-sulfate solutions, the large amounts of ammonium sulfate presented difficulties which interfered with the accuracy of the determinations in every instance.

Sulfuric Acid removed.

In determining the sulfates the small aliquot which had to be taken owing to the amount of sulfates present made a slight error in weighing assume large proportions when figured to sulfates removed from 100 grams of soil. This was especially true of the 2½ normal and 5 normal extracts. In almost every case, however, more sulfates were found in the extracts than were present in the original solutions used. Where this was not the case the difference between the amount present in the original solution and the amount found in the extract was so small as to come easily within the limit of error. The results indicated that there was no accumulation of sulfuric acid in the soil which would cause it to become acid.

Hydrochloric Acid removed.

In trying to determine the amounts of hydrochloric acid in the extract by titration it was found that the ammonium sulfate prevented the development of the color. In making gravimetric determinations no precipitate or cloudiness was observed using 100 cubic centimeter aliquots. This shows that the chlorides if present at all were present in concentrations of less than one part per million of extract, or less than one-tenth of a milligram removed from 100 grams of soil.

Nitric Acid removed.

Nitric acid could not be determined with any degree of accuracy by the colorimetric method. The few determinations made on the more dilute extracts indicated that there was no appreciable difference in amount removed between the different plots. The average amount found was 1.5 parts per hundred thousand.

Iron and Aluminium removed.

The iron determinations could be made colorimetrically only after the largest part of the ammonium sulfate had been removed, as it prevented the development of the color with the thiocyanate. No colorimetric determinations were made on the 2½ normal and 5 normal extracts, as the amount of ammonium sulfate was too large to be driven off by ignition without some mechanical loss.

In the 2½ normal and 5 normal concentrations of ammonium-sulfate extracts, iron and aluminium were determined together by precipitating with ammonia as the hydrate. The precipitates were all light in color, showing that they were mostly aluminium, but all had some iron present.

No iron was found in the extracts from the limed ends of the plots with any of the ammonium-sulfate solutions, except on plot 6 with the 2½ normal solution, and on all the plots with the 5 normal solution. In all the extracts from the unlimed ends of the plots iron was found in varying amounts. A slight increase in the amount removed, with an increase in the concentration of the ammonium-sulfate solution used, was noticed. The largest amount was removed from one of the ammonium-sulfate plots, — No. 8.

TABLE VI. — *Milligrams of Iron Oxide removed from 100 Grams of Air-dried Soil by Different Solutions of Ammonium Sulfate.*

PLOT.	N/10 Solution.	N Solution.
1 UL,	.40	.79
6 UL,	.46	.51
7 UL,	.43	.50
8 UL,	.89	1.02

TABLE VII. — *Milligrams of Iron and Aluminium Oxides removed from 100 Grams of Air-dried Soil by Different Solutions of Ammonium Sulfate.*

PLOT.	N Solution.	2½ N Solution.	5 N Solution.
1 UL,	None.	4.25	6.50
6 UL,	12.00	12.00	33.00
7 UL,	2.00	8.00	7.50
8 UL,	1.50	7.75	28.00
6 L,	None.	2.50	8.00

The most striking difference is in the much larger amount removed from the ammonium-sulfate plot 6 UL.

In trying to purify the precipitates it was found that they contained silica as well as the oxides of iron and alumina.

In order to determine if these precipitates had the same composition in all cases, or varied with the concentration of the solvent used, extracts with different strengths of ammonium-sulfate solutions were made with soil from the unlimed end of plot 6. One-tenth normal, one-half normal and normal concentrations of ammonium-sulfate solutions were employed and the extracts made in the usual way. On addition of ammonium hydrate to the extracts a flocculent precipitate formed, which, after being dried and ignited, proved to have the following approximate composition: —

	Per Cent.
Oxides of iron and aluminium,	75
Silica,	25

The precipitates from the different strengths of ammonium-sulfate solution all had about the same composition. Attempts made to obtain this compound in water extracts were successful when a smaller ratio of soil to water was used and the two left in contact a greater length of time. Soils from the unlimed ends of plots 6 and 8 were used. The extracts were obtained as follows: between 6 and 8 kilos of air-dried soil were placed in a glass jar with an opening in the bottom plugged with glass wool and covered with a linen filter. Enough water was added to just saturate the soil and left for from twelve to twenty-four hours. In the first experiment only as much water was percolated through the soil as was required originally to saturate it. After evaporating the percolate to a small volume, and making slightly acid with hydrochloric acid to decompose any carbonates present, ammonium hydrate was added until the solution was slightly alkaline. A heavy flocculent precipitate, brick red in color, separated out. On filtering, drying and analyzing the precipitate it was found to contain organic matter, calcium, iron and aluminium and silica. The composition of this precipitate varied somewhat from the compound obtained with the ammonium-sulfate solutions. In the ammonium-sulfate extracts the amount of iron and aluminium oxides was about three times the amount of silica found, while with water the percentage of iron and aluminium oxides was almost the same as the per cent. of silica. In the extract made in a similar manner with soil from the unlimed end of plot 8 a precipitate similar in appearance but of a somewhat different composition was found. More silica than iron and aluminium oxides was found.

The increased amount of iron and aluminium found in the extracts with ammonium sulfate over that found in water extracts seems to indicate that in the absence of an available calcium compound the ammonium sulfate attacks the iron and aluminium compounds in the soil.

Investigations in regard to this solvent action of ammonium sulfate on iron and aluminium compounds in the soil are at present being conducted.

Calcium Absorption.

The absorption of calcium by the soil was studied in connection with the determination of soil acidity by the Veitch method. This method is essentially a measure of the absorption of lime by the soil and not a measure of any free acid.

The Veitch method was used on soil from the unlimed and limed ends of plot 6. No difference in the amount of absorbed calcium was noted between the limed and unlimed areas, both having absorbed at the rate of 2,545 pounds of calcium oxide per acre (2,000,000 pounds of soil per acre).

A second method, using the same substance, was also tried. In this method 100 grams of air-dried soil were shaken with 500 cubic centimeters of a saturated calcium-hydrate solution and filtered after two hours. An aliquot of the filtrate was then titrated and the amount of absorbed lime determined. This method gave a much higher absorption than was found by the Veitch method. No difference in the amount of calcium absorbed between the limed and unlimed ends was observed. The calcium oxide absorbed was equal to 11,776 pounds per acre.

A third method, taking a solution of calcium sucrate, was also used. Ten grams of soil were shaken with 50 cubic centimeters of the solution, filtered after two hours and an aliquot titrated. Two strengths of the calcium-sucrate solution were used, — a saturated solution and another one-tenth as strong. The absorption of calcium was the same with both solutions and on both the limed and unlimed areas. The absorption was much greater than with either of the two previously mentioned methods. The unlimed end absorbed at the rate of 26,660 pounds of calcium oxide per acre, while the limed end absorbed at the rate of 23,850 pounds per acre. The greater absorption of the calcium from the sucrate solutions is due to the greater concentration of calcium in these solutions. The Veitch method does not measure the true absorptive capacity of the soil, but measures the absorption up to the point of alkalinity of the soil. That the soil can absorb more calcium after the point of alkalinity is reached is shown by the results obtained by the other methods. With the calcium-sucrate solution the limit of the amount of calcium which the soil can absorb seems to have been reached, as with an increase in the concentration no increase in the amount of calcium absorbed is noted.

It is of interest to compare the results obtained by the above methods with the calcium oxide equivalent obtained with the Hopkins method of determining soil acidity. With this method a marked difference between the limed and unlimed areas of plot 6 is found. The unlimed area has a much higher calcium oxide equivalent than the limed area. The calcium oxide equivalent of the limed end is 631 pounds of calcium oxide per acre, while the unlimed gives an equivalent of 4,976 pounds per acre.

This "acidity," however, is not due to the presence of free acids, either soluble or insoluble in water, but is probably due to the presence of iron and aluminium salts. When the soils are shaken up with the normal potassium-nitrate solution, as the method calls for, an action resembling a double decomposition takes place between the iron and aluminium compounds and the potassium nitrate, with the formation of the easily hydrolyzable iron and aluminium nitrates which go into solution. When the aliquot is titrated the titration shows the amount of nitric acid present in combination with iron and aluminium, as is evidenced by the heavy flocculent precipitate which forms during the titration. In order to determine if nitrates of iron and aluminium hydrolyze readily, known solutions of those salts were made up and titrated. It was found that the entire quantity of nitric acid present could be titrated.

Summarizing the results obtained by the different methods, we find that the soil absorbs increasing amounts of calcium from increasing concentrations of calcium solutions, and that the limed and unlimed plots absorb practically like amounts of actual calcium.

ANALYSIS OF DRAINAGE WATERS.

To determine if the composition of the drainage waters would throw any light on the effect of long-continued use of ammonium sulfate as a fertilizer, the following analyses of drainage waters from the plots studied in the first part of this bulletin were undertaken.

The drainage waters were collected in the spring and fall of 1912 and 1913. Most of the samples were collected in the spring after the frost had left the ground. Only three samples were taken in the late fall. No drainage took place during the summer and early fall. The waters at all times were clear and free from sediment of any kind. In the spring of 1912 five sets of samples were collected, — the first on March 18 and the last on May 17. In the fall a set of samples was collected on November 5 and December 6. In 1913 the first samples were taken on March 9. Five subsequent sets of samples were taken at intervals of one week. Another set was obtained on December 8.

The waters were analyzed for total solids, fixed solids, calcium, sodium, potassium, iron, chlorides and sulfates. As the nitrates vary between wide limits within short spaces of time no attempts were made to determine them, except when the water could be analyzed as soon as collected. Iron was found in traces only in any of the waters.

The amount of drainage varied considerably between the different plots. The amount can be estimated only by the apparent flow from the outlets. Plot 0 had the largest amount, with plots 1 and 7 closely following in the order named. Plots 6 and 8 had the smallest amount. The differences can be explained in part by the general slope of the field. Plots 0 and 1 are the lowest in the field. While the slope is not great it is probably enough to cause some increase on the lower plots. The actual amount of drainage for the year could not be determined, as means for measuring the flow were not available.

TABLE VIII. — *Average Composition of Drainage Waters in Parts per 100,000.*

1912.

PLOT.	TOTAL SOLIDS.		LOSS ON IGNITION.		CALCIUM OXIDE.		SULFUR TRIOXIDE.		CHLORINE.	
	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.
0, ...	16.86	17.95	5.0	6.6	2.06	4.25	5.36	6.07	1.42	1.66
1, ...	24.60	27.60	7.2	7.9	2.43	4.30	8.16	7.87	3.05	4.27
6, ...	27.60	35.50	5.7	8.9	4.39	11.85	11.61	13.29	2.81	3.99
7, ...	21.30	23.40	7.0	6.9	2.49	7.20	8.72	8.17	2.15	3.58
8, ...	30.30	32.90	7.5	7.8	4.82	10.45	12.95	12.79	2.55	3.15

TABLE VIII. — *Average Composition of Drainage Waters in Parts per 100,000* — Concluded.

1913.

PLOT.	TOTAL SOLIDS.		LOSS ON IGNITION.		CALCIUM OXIDE.		SODIUM AND POTASSIUM CHLORIDES.	SULFUR TRIOXIDE.		CHLORINE.	
	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.	Spring.	Spring.	Fall.	Spring.	Fall.
0, . .	17.9	22.6	3.78	6.4	4.05	4.51	5.0	6.92	7.67	1.26	1.45
1, . .	22.7	27.5	3.50	5.0	3.82	3.99	10.2	6.86	7.61	3.19	4.97
6, . .	24.0	33.1	5.46	6.3	6.71	8.30	4.6	8.88	11.13	2.79	4.83
7, . .	20.2	26.9	4.72	6.0	5.24	6.73	4.9	6.49	6.65	2.72	5.62
8, . .	26.4	36.8	5.28	6.5	8.03	9.67	5.2	9.79	11.70	2.88	5.35

Comparing the results plot by plot the first difference noted is in the amount of total solids removed. More soluble salts are removed from the two sulfate plots 6 and 8 than from any of the others. The same is true of the calcium removed, the ammonium sulfate evidently reacting with the calcium in the soil to form calcium sulfate. This is borne out by the increase in the amount of sulfates removed from these two plots. These results are similar to those obtained by Lawes and Gilbert at Rothamstead, in their study of the drainage waters from ammonium-sulfate-treated plots in comparison with those differently fertilized. The protective action of sodium nitrate for calcium is again shown, as the amount of calcium removed from the nitrate plot 1 is smaller than that removed from the other plots. The increase in the amount of sodium and potassium chlorides removed from this plot is due to the sodium nitrate. While the above table would lead one to think that the drainage waters from the different plots had a radically different composition from one another, this is not true, as a study of the average percentage composition of the fixed solids will show.

TABLE IX. — *Average Percentage Composition of Fixed Solids.*

1913.

PLOT.	CALCIUM OXIDE.		SULFUR TRIOXIDE.		CHLORINE.	
	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.
0,	28	28	48	47	9	9
1,	21	18	40	34	19	22
6,	36	31	48	42	15	18
7,	33	32	42	32	18	27
8,	36	32	47	38	14	11

While the waters differ somewhat in their composition, the main difference between them is in the concentration. The waters from the sulfate plots are more concentrated than the others.

The theory that calcium, when removed from the soil through fertilization with ammonium sulfate, is removed in the form of calcium sulfate is borne out by the above results. This is more clearly shown by the ratio of calcium oxide to sulfur trioxide, which is fairly constant for the plots.

As the waters from the limed and unlimed parts of the plots cannot be kept separate, the differences due to liming one-half of each plot cannot be determined. To determine if possible whether any differences existed, the following experiment was conducted with soil from the limed and unlimed areas of plots 5 and 6.

Galvanized-iron cylinders 3 inches in diameter were driven into the soil to a depth of 8 inches, and a column of soil thus removed. The soil was left in the cylinder just as it was removed and taken to the laboratory. A linen cloth filter was then placed over the bottom of the cylinder and the soil saturated with distilled water. When saturated, 500 cubic centimeters of distilled water were poured on top and allowed to percolate through. This was repeated five times, making six percolates from each sample. Three samples from each plot were treated in this way.

For purpose of analysis the second to the sixth percolates, inclusive, were combined into one sample. The solutions were then analyzed for total and fixed solids, calcium, sodium, potassium, magnesium, iron, aluminium, sulfates and chlorides.

TABLE X. — *Composition of Percolates in Parts per 100,000.*

	PLOT 5 L.		PLOT 5 UL.		PLOT 6 L.		PLOT 6 UL.	
	First.	Combined.	First.	Combined.	First.	Combined.	First.	Combined.
Total solids, ...	83.10	23.20	79.30	27.50	89.90	24.50	112.30	29.70
Fixed solids, ...	67.30	18.60	66.40	23.50	72.20	19.70	97.30	24.00
Calcium oxide, . .	22.45	5.68	17.43	4.92	23.75	6.65	25.53	6.44
Potassium oxide, . .	.85	.44	3.16	1.80	1.03	.50	3.57	2.36
Magnesium oxide, . .	1.78	1.11	1.99	.65	.77	.35	1.13	–
Sulfur trioxide, . .	41.60	10.53	40.09	13.50	28.71	9.59	30.77	13.82
Chlorine, ...	1.26	.17	.80	.20	10.38	.49	22.45	2.89

TABLE XI. — *Percentage Composition of Fixed Solids.*

	PLOT 5 L.		PLOT 5 UL.		PLOT 6 L.		PLOT 6 UL.	
	First.	Combined.	First.	Combined.	First.	Combined.	First.	Combined.
Calcium oxide, . .	33.36	30.54	26.25	20.94	32.89	33.76	26.24	26.83
Potassium oxide, . .	1.26	2.37	4.76	7.66	1.43	2.53	3.67	9.83
Magnesium oxide, . .	2.64	5.97	2.99	2.76	1.07	1.78	1.16	–
Sulfur trioxide, . .	61.81	56.61	60.38	57.45	39.76	48.68	31.62	57.58
Chlorine, ...	1.87	.91	1.20	.85	14.38	2.48	23.07	12.04

The first difference noticed on studying Table X. is the larger amount of soluble salts removed in the first percolate than in the subsequent portions. That this difference is largely a matter of concentration is shown by a comparison of the constituents as shown in Table XI. The variations between the two plots are those due to the different fertilizers used. Plot 5 has more sulfates and magnesium and less chlorides removed than plot 6. Since plot 5 received its application of potash as low-grade sulfate and plot 6 as muriate of potash, these differences were to be expected.

The variations between the limed and unlimed ends of the plots are very similar. More calcium and less potash are removed from the limed ends than from the unlimed. Traces of iron and aluminium were found in all of the extracts, but showed no difference between the two plots or between the limed and unlimed areas of the plots.

Comparing the percentage composition of the percolates and the drainage waters, both based on the fixed solids, we find them agreeing very closely. The per cent. of calcium oxide in the drainage water of 1913 for plot 6 is 36 as against 30 found in the percolation waters from this plot, averaging the limed and unlimed. Sulfates in the drainage waters are 48 per cent. and in the percolates 44 per cent., and chlorides in the drainage waters are 15 per cent. and in the percolates 13 per cent. of the fixed solids. The higher results in the drainage waters are probably due to the fact that more of the drainage comes from the limed ends of the plots than from the unlimed.

Culture Studies.

The first culture work undertaken in connection with this problem was to determine if the infertility of the soils extended to their water extracts, as was found by Whitney,[1] Livingston[2] and others.

The seedlings used were rye, barley and red clover, which were germinated on paraffin-covered wire gauze as described in Bulletin No. 40, Bureau of Soils. When the stems of the seedlings reached a length of one inch they were transferred to notched corks and placed in the culture solutions.

The culture solutions were contained in salt-mouth bottles of 250 cubic centimeters' capacity, with necks having a diameter of 1¼ inches. Four seedlings were placed in each bottle. As each experiment was carried on in triplicate this gave a total of twelve seedlings for each treatment.

The soil extracts were made by mixing two parts water with one part soil and letting the mixture stand for about two hours with frequent shakings, when the water was either poured off or filtered through porcelain filters under pressure.

The first series was conducted with extracts from the limed and unlimed ends of plots 1, 6, 7 and 8. One set was made up with filtered extracts, and a second set with the unfiltered extract. The seedlings used were rye and red clover. The experiment was continued four weeks, at the end of which the plants began to wilt.

The first differences were noted at the end of the first week, the rye seedlings in the extracts from the limed ends of the plots being better than those in the extracts from the unlimed areas. The seedlings in the extracts from the unlimed areas all had a reddish-colored stem, and did not make as good a growth as the others. The clover seedlings showed similar differences, but more in the roots than in the tops. The differences became more marked as time went on, and differences in the root development became noticeable. The roots in the extracts from the unlimed end of plot 6 became stunted and thickened,[3] and the roots in the extract from the unlimed end of plot 8, while not stunted, showed a poorer growth than the others. When the experiment was discontinued the seedlings in the extracts from the limed end of plot 1 and plot 8 were the best, with the poorest in the extracts from the unlimed ends of plots 6 and 8. As the clover seedlings did not make much growth they were omitted in the second series and only barley was used. Barley was chosen, as it has been found to be more sensitive to toxic substances than rye seedlings. The filtered extracts were also omitted, as no difference was noticeable between the filtered and unfiltered extracts in the first series.

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[1] Bul. 23, Bureau of Soils, Whitney and Cameron.

[2] Bul. 28, Bureau of Soils, Livingston *et al.;* Bul. 36, Bureau of Soils, Livingston.

[3] Bul. 161 contains descriptions and photographs of clover roots similar to the roots of seedlings in these cultures.

As in the first series the second was continued four weeks. At the end of the first week no differences were noticeable in the tops, but the roots in the extract from the unlimed end of plot 6 again showed the stunted and thickened appearance. At the end of two weeks the tops in the extracts from the unlimed ends of the plots began to wilt, the tips of the leaves turning white. When the experiment was discontinued the seedlings in the extracts from the limed ends of the plots appeared just about alike, while in the extracts from the unlimed ends the poorest were the seedlings in the extract from plot 6. The seedlings were weighed green, but the weights did not show the differences which were apparent to the eye.

When iron and aluminium compounds were found in the soil it was thought that these might have a toxic influence on plants, so culture work was undertaken, using these salts. The results of this experiment have already been published.[1] It is only necessary to state that iron and aluminium salts are very toxic to clover seedlings, and that in dilute solutions calcium carbonate can overcome the toxicity.

Summary and Conclusions.

The results of the experiments show that —

(*a*) The absorption of ammonia from sulfate of ammonia solutions by the soils studied increases with the increase in the concentration of the ammonium-sulfate solution used. This increase is not strictly proportional to the increase in the concentration of the ammonium-sulfate solutions. The soils from two plots previously fertilized with ammonium sulfate without lime absorb less ammonia than do the other soils. This shows that the continued use of ammonium sulfate has caused some change in the soil.

(*b*) The absorption of dyes by these soils is very similar to the absorption of ammonia. More dye is absorbed from the more concentrated solution than from the lesser concentration. The two unlimed sulfate plots also absorb less than do the others, showing that their absorptive powers have been lessened.

(*c*) Ammonium sulfate has a solvent action on the calcium in the soils, and depletes the soil of this element. This is shown by the ammonium-sulfate extracts and also by the drainage water analyses.

(*d*) Ammonium sulfate seems to have no solvent action on sodium or potassium in the soil in the presence of sufficient quantities of lime. That it has a slight solvent action on potassium in the absence of lime is shown in the percolation experiment, where more is removed from the unlimed plots than from the limed. This may be more beneficial than harmful, as it will make more potash available for the use of plants.

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[1] Bul. 161, Mass. Exp. Sta., 2d part.

(*e*) The use of ammonium sulfate probably does not cause the accumulation of sulfates in the soil, as is indicated by the marked removal of sulfates from the sulfate plots in all of the experiments. All of the soil extracts were neutral to indicators, showing that no free soluble acids were present in the soil. The absence of free acids is further shown by the amounts of calcium absorbed. Using different calcium solutions, no difference in the amount of calcium absorbed is found between the limed and unlimed ends. If a free acid or acids were present in the soil from the unlimed areas, these soils should have absorbed a greater amount of lime than the soils from the limed areas of the plots.

Whether the action of the ammonium sulfate in the soil is one of double decomposition between the ammonium sulfate and calcium carbonate, or in its absence some other salts, or whether the ammonia is first absorbed physically, and the sulfuric acid thus set free reacts with the calcium, is still a matter of dispute. While the results obtained do not prove either of these theories to be correct, they seem to indicate that it may be a combination of these two that takes place.

The similarity between the absorption of ammonia and the absorption of dyes is evidence that the ammonia is held by physical rather than chemical forces. That it is not purely a chemical exchange is shown by the increased amounts absorbed with the increased concentrations of the solutions used, and, as Voelcker and others have shown, all of the ammonia is never absorbed from a solution, no matter how dilute. That some chemical reaction takes place is shown by the amounts of calcium removed. The amounts removed reach a definite limit, above which none is removed, when the soil is shaken with a normal ammonium-sulfate solution.

What takes place in soil fertilized with ammonium sulfate may be as follows: the first reaction to take place is the physical absorption of the ammonia, thus setting free sulfuric acid. If, after the soil has absorbed all the ammonia it is capable of holding, some ammonium sulfate remains, double decomposition takes place. In both cases the first salt to be attacked is probably the calcium carbonate, and it is only in the absence of this salt that the iron and aluminium compounds are attacked. It is to these salts of iron and aluminium that the infertility of the plots continuously fertilized with sulfate of ammonia appears to be due.

BULLETIN No. 166 DECEMBER, 1915

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION.

IMPROVED METHODS FOR FAT ANALYSIS.

By E. B. Holland, J. C. Reed and J. P. Buckley.

This bulletin presents the results of a careful study of methods for the analysis of oils and fats. In most cases the work has resulted in improvements in manipulation and in the apparatus employed. The Hehner and Mitchell method has been adapted for use with the insoluble acids of butter fat, the original method not proving applicable. The method for the determination of acetyl number may be considered new and that for unsaponifiable matter substantially so. Information is given as to the interpretation of the results obtained. The bulletin is technical in character, being intended primarily for those engaged in the examination of these substances.

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[1] On account of ill health not in administrative charge.

[2] In administrative charge.

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IMPROVED METHODS FOR FAT ANALYSIS.

E. B. HOLLAND, J. C. REED AND J. P. BUCKLEY.[1]

INTRODUCTION.

Experiments in animal nutrition have constituted a prominent line of investigation at the Massachusetts Agricultural Experiment Station ever since its organization, and numerous attempts have been made to determine the effect of feed on the composition of the resulting butter fat.[2] These experiments extended over a number of years and required the analysis of many samples of fat. A careful study of the technique of fat analysis, in so far as the more common group methods are concerned, was undertaken at the outset and has been continued to the present time. With increasing experience, plans were formulated for a systematic correlation and standardization of the various processes, and considerable progress has been made in that direction. The object was to promote accuracy by greater uniformity and simplicity of methods, embracing definition of terms, principles involved and details of manipulation, including reagents, apparatus and glassware. A report on "Methods for Fat Analysis"[3] was published some years ago.

Innumerable modifications suggested by foreign and American investigators in addition to those resulting from our own initiative have necessitated a complete revision of former methods. While these in turn will be superseded in the light of subsequent progress, they are offered in the hope that they may prove of service to fellow workers in oils and fats.

At the outset oils, fats and waxes are defined, classified, and a synopsis of composition given in order that the value of the data contributed by the various determinations whereby the "structural" composition of the product is evolved may be fully understood. The organoleptic tests are merely enumerated, as their application is self-evident. They are employed in classification, are very serviceable in identification, and particularly valuable in discriminating as to quality or grade, for which experience and general knowledge of the trade are essential.

The more prominent physical tests are of such a well-known character that time is not taken to consider their special modifications. They furnish a certain amount of confirmatory evidence, and are occasionally employed for "culling" suspicious samples. With lubricating and illuminating (hydrocarbon) oils they are far more important. The chemical methods are indispensable for determining the identity, composition and quality of oils and fats, and are treated in a monographical way.

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[1] Mr. Reed was associated in the earlier and Mr. Buckley in the later stages of the work.

[2] Rpts. Hatch Expt. Sta., 13, pp. 14–33 (1901); 14, pp. 162–168 (1902); 16, pp. 45–62 (1904). Mass. Agr. Expt. Sta. Rpt. 21, Pt. 2, pp. 66–110 (1909).

[3] Rpts. Mass. Agr. Expt. Sta., 21, Pt. 2, pp. 120–138 (1909); 22, Pt. 1, p. 139 (1910).

In standardizing the methods an effort was made to use not only the same flasks but also the same amount of material, volume of solution and indicator, and the same agent to facilitate boiling and like conditions of treatment in so far as possible. All the methods, practically without exception, have been modified in reagents and manipulation, and attention called to numerous precautions found necessary for accurate work. This is especially noticeable in the determination of insoluble acids, unsaponifiable matter and iodine number. The determination of acetyl number should be considered a new method. The process for determining stearic acid is a modification of the Hehner and Mitchell method adapted for use with the insoluble acids of butter fat for which the original did not prove applicable. The limits of error are original, based chiefly on practical manipulation, although considered on theoretical grounds. The synopsis of reaction expresses the successive steps and underlying principle in each process free from verbiage. The supplementary notes include any information, original or otherwise, that might be of service in interpreting results. All tables and formulas are calculated on the latest atomic weights, and many formulas express old principles in a new light.

This article constitutes a portion of a paper submitted for the degree of doctor of philosophy at the Massachusetts Agricultural College.

Classification — Oils, Fats and Waxes.

Natural oils may be divided into two major groups, *i.e.*, essential, ethereal or volatile oils, and fatty, fixed or nonvolatile oils.

The fatty oils may be subdivided according to consistency at ordinary temperature into oils and fats; according to origin, into vegetable and animal; according to properties, into drying, semidrying and nondrying, etc.

Waxes are generally grouped with the fatty oils on account of their similar chemical structure. Oils and fats are essentially neutral glyceryl esters, compounds of fatty acids and the soluble tribasic alcohol, glycerol. Waxes are composed of esters of fatty acids and insoluble monobasic and occasionally dibasic alcohols, together with a considerable proportion of free alcohols and of hydrocarbons.

Any general classification of oils, fats and waxes, whether of origin, of physical characteristics, or of chemical characteristics, is open to criticism; probably that of Lewkowitsch, based on the magnitude of the iodine number correlated with that of consistency, origin and properties, is the best that has been offered.

Oils, Fats and Waxes.

Oils	Vegetable oils	Drying oils	
		Semidrying oils	Cottonseed oil group Unnamed group Rape oil group
		Nondrying oils	Unnamed group Castor oil group
	Animal oils	Marine animal oils	Fish oils Liver oils Blubber oils
		Terrestrial animal oils	
Fats	Vegetable fats		Chaulmoogra oil group Laurel oil group Palm oil group Myristica group Cacao butter group Coconut oil group Dika fat group Unnamed group
	Animal fats	Body fats Drying fats Semidrying fats Nondrying fats Milk fats	
Waxes	Liquid waxes	Animal waxes	
	Solid waxes	Vegetable waxes Animal waxes	

Organoleptic Tests.

Consistency (20° C.),	Liquid. Semifluid. Solid.
Turbidity,	Water or other nonmiscible substances.
Sediment,	Stearin, tissue, dirt, etc.
Color[1] (0.5 inch cell),	Water white (colorless). Straw color. Lemon yellow. Bright yellow (most oils when refined). Dirty yellow (beeswax). Bright red. Dirty dark red (crude palm oil). Yellowish green (laurel oil). Green (chlorophyll). Brown. Black.

---

[1] Arbitrary commercial terms are often employed in designating oils. A scientific color standard of the Milton Bradley Company's type appears impractical, but Lovibond's tintometer promises more satisfactory results.

Transparency or opacity (0.5 inch cell).	
Fluorescence or bloom, .	Mineral oils, seldom in fatty oils.
Odor (cold and hot), . .	Characteristic of product (fatty acids, amines, etc.).[1] Rancidity.
Taste, ...	Characteristic of product. Finest (first quality), "hard," "harsh." Rancidity.

PHYSICAL TESTS.

Specific gravity, . .	$d\frac{t}{4^\circ C.}$ t = 20°, 40° and 60° C. Coefficient of expansion.
Melting point, . . .	° C. (lower in mixed than in simple glycerides).
Solidifying point, . .	° C.
Refractive index, . .	Abbe refractometer, $n\frac{t}{D}$ t = 20°, 40° and 60° C. Dispersion.
Optical rotation, . .	Dextro rotatory, 200 m.m. tube. Lævo rotatory.
Colorimeter, . . .	Lovibond tintometer, 0.5 inch cell.
Viscosity, . . .	Redwood viscosimeter, 70° Fahr.
Solubility, . . .	Crismer, critical temperature of dissolution, ° C. Valenta test, ° C.
Flash point, . . .	° C.
Ignition point, . . .	° C.

SYNOPSIS OF COMPOSITION — OILS AND FATS.

Neutral fat (glycerides)	Fatty acids Glycerol
Free fatty acids	
Unsaponifiable matter[2]	Sterols[3] Hydrocarbons Chromogenic bodies, resinous substances, etc.

---

[1] The odor of fish oils is said to be due largely to clupanodonic and homologous acids.

[2] Nominally a part of the neutral fat, but differentiated to facilitate subsequent calculations.

[3] Occur as free alcohols and, to some extent, in combination with fatty acids, as esters.

Fatty Acids and Glycerides.

Total fatty acids.		
	Neutralization number	
	Mean molecular weight	
	Fatty acids of neutral fat	Glycerides (neutral fat)
	Neutralization number	Saponification number
	Mean molecular weight	Mean molecular weight
	Glycerol	
	Free fatty acids	
	Neutralization number	
	Mean molecular weight	
	Soluble fatty acids[1]	Glycerides
	Neutralization number	Saponification number
	Mean molecular weight	Mean molecular weight
	Acetic acid	Acetin
	Butyric acid	Butyrin
	Valeric acid	Valerin
	Caproic acid	Caproin
	Caprylic acid	Caprylin
	Capric acid	Caprin
	Glycerol	
	Volatile fatty acids[2]	Glycerides
	Neutralization number	Saponification number
	Mean molecular weight	Mean molecular weight
	Glycerol	
	Insoluble fatty acids[1]	Glycerides
	Neutralization number	Saponification number
	Mean molecular weight	Mean molecular weight
	Lauric acid	Laurin
	Myristic acid	Myristin
	Palmitic acid	Palmitin
	Stearic acid	Stearin
	Arachic acid	Arachin
	Oleic acid	Olein
	Erucic acid	Erucin
	Linolic acid	Linolin
	Linolenic acid	Linolenin
	Clupanodonic acid	Clupanodonin
	Ricinoleic acid	Ricinolein
	Dihydroxystearic acid	Dihydroxystearin
	Glycerol	

SAPONIFICATION (KOETTSTORFER[3]) NUMBER.

The saponification number indicates the number of milligrams of potassium hydroxide required for the complete saponification of 1 gram of an oil, fat or wax.

Reagents. — Alcohol:[4] redistilled, free from acids and aldehydes.

---

[1] The free soluble and insoluble acids should not be calculated to glycerides.

[2] Are considered as constituting a portion of the soluble acids.

[3] Ztschr. Analyt. Chem., 18, pp. 199–207, 431–437 (1879).

[4] To purify alcohol for use as a solvent or reagent in fat analysis, 5 gallons are treated with at least 10 grams of silver nitrate, thoroughly shaken, and allowed to stand to insure oxidation of aldehydes; then, with 1,000 grams of calcium oxide (caustic), repeatedly shaken for several days to remove acids and a portion of the water, filtered and redistilled. Fractionation is necessary if the boiling point exceeds a range of 1° C., the distillate should be preserved in glass and protected from sunlight.

Alcoholic potash solution:[1] 50 cubic centimeters of a saturated solution of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of alcohol. The alkali should be added to the alcohol slowly with agitation in order to prevent any appreciable rise in temperature. The solution should be allowed to stand at least twenty-four hours and filtered immediately before use.

N/2 hydrochloric acid.

Phenolphthalein solution: 1 gram to 100 cubic centimeters of alcohol, neutralized.

Cotton blue 6B[2] solution: 2 grams to 100 cubic centimeters of alcohol. The indicator should be boiled in a flask under a reflux condenser for two hours and then filtered.

Method. — Into a 300 cubic centimeter Erlenmeyer flask are brought 5 grams of fat (care being taken to avoid getting any fat on the sides of the flask), together with 50 cubic centimeters of alcoholic potash,[3] accurately measured with a burette, 50 cubic centimeters of alcohol and several glass beads. The flask is connected with a spiral or other form of reflux condenser and the solution boiled vigorously on a water bath (see Figs. 1 and 2) with occasional rotation until saponification is complete, — about

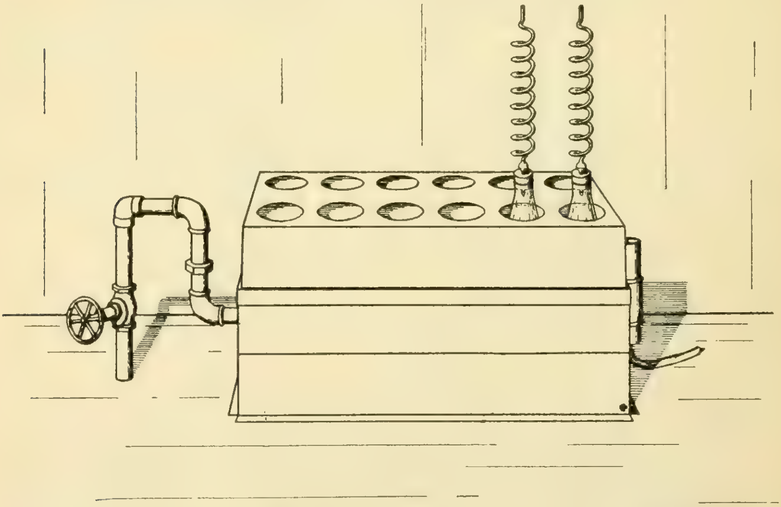

FIG. 1. — Steam-heated water bath employed in the determination of saponification, acid and acetyl numbers and insoluble acids.

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[1] Approximately 0.65 N solution. Alcoholic potash will dissolve about 0.04 gram of potassium carbonate to 100 cubic centimeters, according to Holde. — Chem. Rev. Fett u. Harz Indus., 14, pp. 105-107 (1907).

[2] Sodium salt of triphenylpararosaniline-trisulphonic acid. Obtained from National Aniline and Chemical Company, 100 William Street, New York, N. Y.

[3] For waxes, especially wool wax, potassium alcoholate is preferable on account of its greater efficiency. The solution should be freshly prepared by dissolving 5 grams of metallic potassium in 100 cubic centimeters of absolute alcohol. — Lewkowitsch, Analysis of Oils, Fats and Waxes, 1, p. 107 (1913).

sixty minutes. The reaction is quadrimolecular with triglycerides. The flask is then placed in a water bath at 60° C., and the solution, after cooling to that temperature, titrated with N/2 hydrochloric acid, using 1 cubic centimeter of phenolphthalein as indicator, to the complete elimination of the pink color. The cooling and dilution of the solution, due to the addition of the acid, occasionally give rise to small colored particles; this can be obviated by a slight increase in temperature. The end point is particularly difficult to determine in the presence of aldehydes, which impart a dark reddish-brown color to the solution. Fish oils behave in a like manner. In such cases cotton blue (1 cubic centimeter) is preferable to phenolphthalein. The change in color is from red with alkalies to blue with acids. The two indicators appear to give like results when considered in connection with their respective blanks. Absorption of carbonic acid from the air should be guarded against at all times. As alcoholic potash gradually loses alkalinity on boiling, the operation should be timed with reasonable care. Several blank determinations should be run with every series of tests under precisely similar conditions. The difference between the titration of the blank and that of the excess alkali in the test is the acid equivalent of the fat taken, which should be calculated to milligrams of potassium hydroxide for 1 gram of fat.

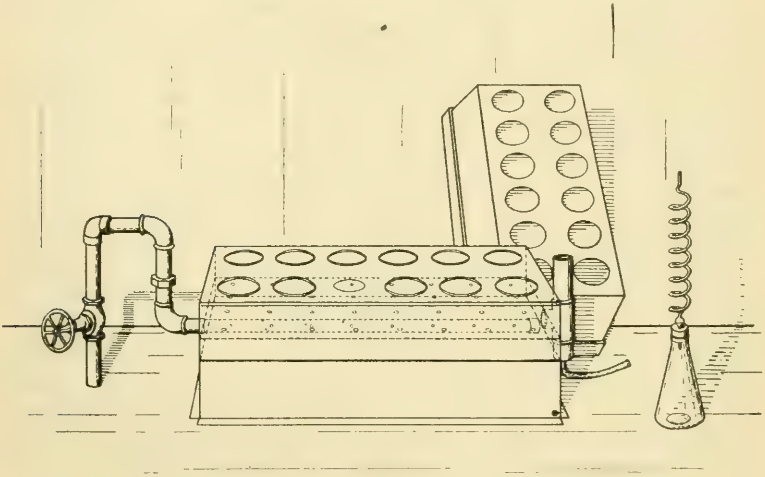

FIG. 2. — Detailed drawing of Fig. 1.

1 cubic centimeter of N/2 acid is equivalent to 28.054 milligrams of potassium hydroxide.

Limit of error, 0.50 milligram.

Synopsis of Reaction.

$$\underset{\text{fat}}{(RCOO)_3C_3H_5} + \underset{\text{alkali}}{3\,KOH} = \underset{\text{salt}^1}{3\,RCOOK} + \underset{\text{glycerol}}{C_3H_5(OH)_3}$$

---

[1] The term "soap" is now limited by custom to the alkali salts of insoluble fatty acids.

Titration of excess alkali.

R in the graphic formula of the fatty acids represents C and H in different amounts, according to the acid, but in the proportion of C_nH_{2n+1}, except in the case of unsaturated and of dibasic acids.

Saponification Numbers of Triglycerides.

GLYCERIDE.	Formula.	Molecular Weight.	Saponification Number.
Acetin,	$(CH_3COO)_3C_3H_5$	218.112	771.732
Butyrin,	$(C_3H_7COO)_3C_3H_5$	302.208	556.981
Valerin,	$(C_4H_9COO)_3C_3H_5$	344.256	488.950
Caproin,	$(C_5H_{11}COO)_3C_3H_5$	386.304	435.729
Caprylin,	$(C_7H_{15}COO)_3C_3H_5$	470.400	357.832
Caprin,	$(C_9H_{19}COO)_3C_3H_5$	554.496	303.562
Laurin,	$(C_{11}H_{23}COO)_3C_3H_5$	638.592	263.586
Myristin,	$(C_{13}H_{27}COO)_3C_3H_5$	722.688	232.914
Palmitin,	$(C_{15}H_{31}COO)_3C_3H_5$	806.784	208.636
Stearin,	$(C_{17}H_{35}COO)_3C_3H_5$	890.880	188.941
Arachin,	$(C_{19}H_{39}COO)_3C_3H_5$	974.976	172.644
Olein,	$(C_{17}H_{33}COO)_3C_3H_5$	884.832	190.233
Erucin,	$(C_{21}H_{41}COO)_3C_3H_5$	1,053.024	159.848
Linolin,	$(C_{17}H_{31}COO)_3C_3H_5$	878.784	191.542
Linolenin,	$(C_{17}H_{29}COO)_3C_3H_5$	872.736	192.869
Clupanodonin,	$(C_{17}H_{27}COO)_3C_3H_5$	866.688	194.215
Ricinolein,	$(C_{17}H_{32}.OH.COO)_3C_3H_5$	932.832	180.444
Dihydroxystearin,	$(C_{17}H_{33}(OH)_2COO)_3C_3H_5$	986.880	170.562

Supplementary Notes. — The term "saponification or saturation equivalent," as employed by Allen[1] and others, indicates the grams of fat that are saponifiable with one equivalent of potassium hydroxide in grams (56.108); in other words, the grams of fat saponifiable with 1 liter of N potassium hydroxide.

$$\text{Saponification equivalent (sq)} = \frac{56108}{s} \text{ or } \frac{\text{mg. of fat}}{\text{c.c. N alkali}};$$

$$\text{Saponification number (s)} = \frac{56108}{sq}.$$

The lower the molecular weight of the fatty acids (or esters) the more alkali will be required to satisfy 1 gram, and the higher will be the saponification number. The presence of free fatty acids increases the saponification number, and unsaponifiable matter decreases it. The majority of oils and fats have saponification numbers lying between 185 and 200, with a mean of approximately 193. While the numbers for different products are quite characteristic they are by no means fixed or constant, varying with the state of purity and rancidity. The character of an oil or fat is affected also by natural conditions, such as climate, soil, food supply and other factors influencing formation or production, and by method of separation or preparation.

---

[1] Commercial Organic Analysis, 2, pp. 15, 16 (1910).

Fats and oils containing a considerable amount of the glycerides of the lower (volatile) fatty acids and of myristin are characterized by a saponification number exceeding 200. Among the more prominent of these, testing from 210 to 290, are croton oil, spindle tree oil, turtle, dolphin jaw, porpoise jaw and brown fish of the blubber oils, several of the myristica group, the coconut oil group including palm-nut, coconut and other less common oils, the dika fat group, Japan wax and butter fat. Oils and fats containing a considerable proportion of glycerides of the higher fatty acids, particularly hydroxy acids, are characterized by low saponification numbers. Castor oil, consisting largely of ricinolein, has a saponification number of about 185. The rape oil group, including rape (colza) and various mustard oils, have saponification numbers of about 175, on account of the large proportion of erucin.

Liquid and solid waxes, such as sperm oil, flax wax, wool wax, beeswax, spermaceti, insect wax, etc., are characterized by extremely low saponification numbers, from 80 to 140, due to the large proportion (nearly one-half) of monobasic alcohols and of hydrocarbons.

Monoglycerides, with only one acid radical, and diglycerides, with two, have a lower saponification number than the corresponding triglycerides with three acid radicals.

Glycerides can also be hydrolyzed by concentrated mineral acids; by superheated steam with a catalyzer such as hydrochloric acid or with an accelerator such as caustic lime, potash or other oxide; by enzymes; by sulfoaromatic compounds such as Twitchell reagent, etc.

ACID NUMBER.

The acid number indicates the number of milligrams of potassium hydroxide required to neutralize the free fatty acids in 1 gram of an oil, fat or wax.

Reagents. — Alcohol: redistilled, free from acids and aldehydes.

N/10 potassium (or sodium) hydroxide.

Phenolphthalein solution: 1 gram to 100 cubic centimeters of alcohol, neutralized.

Cotton blue 6B solution: 2 grams to 100 cubic centimeters of alcohol. The indicator should be boiled in a flask under a reflux condenser for two hours and then filtered.

Method. — Ten grams of fat are brought into a 300 cubic centimeter Erlenmeyer flask, together with 100 cubic centimeters of alcohol and several glass beads. The flask is connected with a spiral or other form of reflux condenser and the solution brought to boil on a water bath to insure solution of the free fatty acids. The boiling should not be prolonged, as esterification is liable to result. The flask is then placed in a water bath at 60° C., and the solution after cooling to that temperature titrated with N/10 alkali, using 1 cubic centimeter of phenolphthalein as indicator, to the appearance of a pink tint. N/2 alkali is preferable for high percentages of free acids, preventing unnecessary dilution and cooling of the solution which otherwise might cause partial hydrolysis of the resulting soap[1] if the alcoholic strength fell below 40 per cent.[2] In practical work, however, at least 50 per cent. is advisable. As the change in color with phenolphthalein is gradual in many instances, without a sharply defined end point, cotton blue (1 cubic centimeter) offers certain advantages in such cases, as it yields a pronounced red and is more decisive. The coloration is not permanent with either indicator because of the saponification of neutral esters and the decolorizing action of carbonic acid absorbed from the air on shaking. Thorough shaking during titration, however, is essential, although the color persists for only a short time. Several blank determinations should be run on the alcohol with every series of tests, and deducted. Redistilled alcohol should be practically neutral, or can be readily made so by the addition of alkali.

1 cubic centimeter of N/10 alkali is equivalent to 5.6108 milligrams of potassium hydroxide.

Limit of error, 0.10 milligram.

Synopsis of Reaction.

$$RCOOH + KOH = RCOOK + H_2O$$

Supplementary Notes. — Koettstorfer expresses the acidity in cubic centimeters of N potassium hydroxide required for 100 grams of fat as "degrees of acidity." Stockmeier[3] reports "degrees of rancidity" in the same manner. Ten grams of fat with N/10 alkali are, however, a more convenient amount with which to work.

1° rancidity = .56108 acid number
1 acid number = 1.78228° rancidity

The amount of free acids in lubricating oils is sometimes reported in terms of sulfuric anhydride (SO_3).

The acid number of oils and fats varies with the purity, age and amount of hydrolysis and of oxidation they have undergone. Contact with fermenting or decaying matter, such as animal tissue, casein of butter and the marc of fruits, tends to rapidly increase the amount of free acids. Acidity is not a measure of rancidity, as hydrolysis may result from the action of enzymes (lipases) in the presence of moisture without accompanying oxidation, which appears necessary for the production of strong-smelling, acrid-tasting bodies (such as aldehydes, ketones, free volatile acids and esters of acids of low molecular weight) that characterize rancid products. Rancidity is due, apparently, to the simultaneous action of oxygen and of light on free fatty acids, and on glycerol. The latter does not seem to occur free, but appears to be decomposed immediately on formation. Rancidity develops more readily in liquid oils in which olein predominates than in the solid fats which are composed more largely of palmitin and stearin. Fresh animal fats are practically free from acid, while vegetable oils seem to contain a small amount. Relatively large amounts of free fatty acids are sometimes found in corn, sesame, peanut, rice, olive (especially "bagasse" olive oils), and Japanese sardine oils, in the so-called vegetable butters and tallows and other vegetable fats, particularly palm oil, and in bone fat, beef tallow and butter. The amount of free fatty acids in waxes is probably smaller and the variation less than in oils and fats, although carnauba wax and especially beeswax appear to contain considerable. In a measure, acid number indicates "quality" of the product.

---

[1] On diluting and cooling a clear hot solution of neutral alkali palmitate or stearate (RCOOK), a precipitate containing more than one equivalent of fatty acids to one of alkali is produced, and the ratio tends to increase with greater dilution. Neutral oleate acts in a like manner, although investigators differ as to its relative stability. Holde claims that 80 per cent. alcohol is necessary to prevent hydrolysis of the oleate.

[2] Kanitz, Ber. Deut. Chem. Gesell. 1903, p. 400. (From Lewkowitsch.)

[3] Abstract, Vrtljschr. Chem. Nahr. u. Genussmtl. 4, pp. 428–429 (1889).

Mineral acids when present may be determined by shaking out with hot water in a separatory funnel, and by titrating the solution when cold with N/2 or N/10 alkali (according to the amount of acids present), using 1 cubic centimeter of methyl orange (1 to 1,000) as indicator. Methyl orange is not affected by carbonic acid, or by the insoluble fatty acids, and only to a limited extent by the soluble fatty acids, and is, therefore, well adapted for the purpose.

Mineral lubricating oils should not contain an appreciable amount of free acids. The acidity may be due to sulfuric acid from the refining process, to resinous bodies or to naphthenic acids. These acids should be neutralized with alkali and removed by washing or by sedimentation and filtration.

ETHER (ESTER) NUMBER.

The ether number indicates the number of milligrams of potassium hydroxide required for the saponification of the neutral esters in 1 gram of an oil, fat or wax.

The ether number is represented by the difference between the saponification and acid numbers, and in cases where there are no free fatty acids present is identical with the saponification number.

Supplementary Notes. — Natural fats, both animal and vegetable, contain practically only triglycerides, — neutral glyceryl esters. These glycerides may occur, however, to some extent as complex molecules (mixed triglycerides) instead of simple. The composition of mixed glycerides is difficult to determine, as they appear to suffer intramolecular changes on being treated with a solvent.

Monoglycerides and diglycerides apparently never occur in nature nor, to any appreciable amount, in freshly prepared oils and fats. The presence of free fatty acids indicates previous hydrolysis of the triglycerides, and hydrolysis conditions the presence of monoglycerides and diglycerides; therefore the so-called ether number loses its definite character as free acids increase.

CALCULATED DATA FROM SAPONIFICATION, ACID AND ETHER NUMBERS.

Glycerol. — In the saponification of any triglyceride, 3 molecules, or 168.324 parts, of potassium hydroxide combine with 1 molecule of fat, setting free 1 molecule, or 92.064 parts, of glycerol; therefore 1 gram of potassium hydroxide is equivalent to .54695 gram of glycerol.

$$\underset{\text{fat}}{(RCOO)_3C_3H_5} + \underset{\text{alkali}}{3\ KOH} = \underset{\text{glycerol}}{C_3H_5(OH)_3} + \underset{\text{salt}}{3\ RCOOK}$$

The percentage of glycerol (G) can be calculated from the ether number (e) by means of the formula[1] —

$$G = .00054695\ e \qquad (1)$$

This formula is not applicable in the case of fats containing monoglycerides and diglycerides. The higher the saponification number or, in other words, the lower the mean molecular weight of the constituent acids, the greater the proportion of glycerol. Monoglycerides and diglycerides contain a larger proportion of glycerol than the triglycerides.

Total Fatty Acids. — In the saponification of a fat, 3 molecules, or 54.048 parts, of water are required for every molecule, or 92.064 parts, of glycerol separated.

$$\underset{-}{(RCOO)_3C_3H_5} + \underset{54.048}{3\ H_2O} = \underset{92.064}{C_3H_5(OH)_3} + \underset{-}{3\ RCOOH}$$

The percentage of total fatty acids (T) in 1.00 part of fat can be calculated from the percentage of glycerol (G) by means of the formula[2] —

$$T = 1.00 + \frac{54.048}{92.064} G - G \quad \text{or}$$

$$1.00 - \frac{38.016}{92.064} G$$

and substituting the value of glycerol in terms of ether number (e): —

$$T = 1.00 - \left(\frac{38.016}{92.064} \times .00054695\ e\right) \quad \text{or}$$

$$1.00 - .00022585\ e \qquad (2)$$

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[1] Zulkowski, Ber. Deut. Chem. Gesell. 16, p. 1140.

[2] *Loc. cit.*, p. 1315.

In other words, assuming a fat to be composed of a mixture of triglycerides and free fatty acids, if the group C_3H_2 in an amount proportional to the glycerol content be deducted from 1.00, the percentage of total fatty acids may be obtained.

$$\underset{\text{Neutral fat}}{(RCOO)_3C_3H_5} + \underset{\substack{\text{Free}\\\text{fatty}\\\text{acids}}}{RCOOH} - C_3H_2 = \underset{\substack{\text{Total}\\\text{fatty}\\\text{acids}}}{4\ RCOOH}$$

$$T = 1.00 - \frac{38.016}{92.064}\ G \quad \text{or}$$

$$1.00 - .00022585\ e \tag{2}$$

In case of fats containing appreciable amounts of unsaponifiable matter proper correction should be made for the same.

Neutralization Number and Mean Molecular Weight of Total Fatty Acids. — The neutralization number (n) and mean molecular weight (m) of the total fatty acids (T) can be calculated from the ether (e) and saponification (s) numbers by means of the formulas —

$$n = \frac{s}{T} \quad \text{or}$$

$$\frac{s}{1.00 - .00022585\ e} \tag{3}$$

$$m = \frac{56108}{n} \tag{4}$$

Neutralization Number and Mean Molecular Weight of Fatty Acids in Neutral Fat. — The molecular weight (m_1) and neutralization number (n_1) of the acids in the neutral fat can be calculated from the ether number (e) and the percentage of neutral fat (N) — determined either gravimetrically or by difference[1] — by the formulas[2] —

$$\text{Molecular weight of neutral fat} = \frac{3 \times 56108}{e} \times N \quad \text{or}$$

$$\frac{168324\ N}{e}$$

$$\text{Molecular weight of neutral fat} = 3\ (m_1 - H) + C_3H_5 \quad \text{or}$$

$$3\ m_1 + C_3H_2 \quad \text{or}$$

$$3\ m_1 + 38.016$$

$$3\ m_1 + 38.016 = \frac{168324\ N}{e}$$

$$m_1 = \frac{56108\ N}{e} - 12.672 \tag{5}$$

$$n_1 = \frac{56108}{m_1} \tag{6}$$

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[1] The unsaponifiable matter is a source of error unless deducted.

[2] Wright, Analysis of Oils, etc., p. 130 (1903).

The neutralization number (n_1) and molecular weight (m_1) of the acids in the neutral fat can also be calculated from the ether number (e) and the percentage of total fatty acids (T) and free fatty acids (A) by the formula —

$$n_1 = \frac{e}{T - A} \qquad (7)$$

T — A may be derived from formulas (2) and (16).

$$m_1 = \frac{56108}{n_1} \qquad (8)$$

Mean Molecular Weight and Saponification Number of Neutral Fat. — The molecular weight (m_2) of the neutral fat can be calculated from the ether number (e) and the percentage of neutral fat (N) as shown above by the formula —

$$m_2 = \frac{3 \times 56108}{e} \times N \quad \text{or} \quad \frac{168324\ N}{e} \qquad (9)$$

or from the mean molecular weight (m_1) of the acids of the neutral fat: —

$$m_2 = 3\ m_1 + 38.016 \qquad (10)$$

The saponification number (s_2) can be calculated from the mean molecular weight (m_2) by means of the formula —

$$s_2 = \frac{3 \times 56108}{m_2} \qquad (11)$$

Fatty Acids and Glycerol in Neutral Fat. — The percentage of fatty acids (F) and of glycerol (G) in neutral fat can be calculated from the percentage of neutral fat (N) and the mean molecular weight (m_1) of the fatty acids in the neutral fat:[1] —

$$(RCOO)_3C_3H_5 + 3\ H_2O = 3\ RCOOH + C_3H_5(OH)_3$$

$$F = \frac{3\ m_1}{3\ m_1 + C_3H_2} \times N \qquad (12)$$

$$G = \frac{92.064}{3\ m_1 + 38.016} \times N \qquad (13)$$

The percentage of glycerol (G) in neutral fat (N) can also be calculated from the percentage (F) and molecular weight (m_1) of the acids of neutral fat by the formula —

$$N = \frac{3\ m_1 + C_3H_2}{3\ m_1} \times F \quad \text{or} \quad \frac{3\ m_1 + 38.016}{3\ m_1} \times F$$

$$G = \frac{C_3H_5(OH)_3}{3\ m_1 + C_3H_2} \times N \quad \text{or} \quad \frac{92.064}{3\ m_1 + 38.016} \times N$$

---

[1] A close approximation can usually be obtained by using the mean molecular weight of the total fatty acids.

substituting the value of N in terms of F and m_1 : —

$$G = \frac{92.064}{3\,m_1 + 38.016} \times \frac{3\,m_1 + 38.016}{3\,m_1} \times F$$

$$\frac{92.064}{3\,m_1} \times F \qquad (14)$$

The total fatty acids are equal to the sum of the fatty acids in the neutral fat and the free fatty acids.

Percentage of Fatty Acids and Glycerol in Triglycerides.

GLYCERIDES.	Formula.	Fatty Acids (Per Cent.).	Glycerol (Per Cent.).
Acetin,	$(CH_3COO)_3C_3H_5$	82.570	42.210
Butyrin,	$(C_3H_7COO)_3C_3H_5$	87.421	30.464
Valerin,	$(C_4H_9COO)_3C_3H_5$	88.957	26.743
Caproin,	$(C_5H_{11}COO)_3C_3H_5$	90.159	23.832
Caprylin,	$(C_7H_{15}COO)_3C_3H_5$	91.918	19.571
Caprin,	$(C_9H_{19}COO)_3C_3H_5$	93.144	16.603
Laurin,	$(C_{11}H_{23}COO)_3C_3H_5$	94.047	14.417
Myristin,	$(C_{13}H_{27}COO)_3C_3H_5$	94.740	12.739
Palmitin,	$(C_{15}H_{31}COO)_3C_3H_5$	95.288	11.411
Stearin,	$(C_{17}H_{35}COO)_3C_3H_5$	95.733	10.334
Arachin,	$(C_{19}H_{39}COO)_3C_3H_5$	96.101	9.443
Olein,	$(C_{17}H_{33}COO)_3C_3H_5$	95.704	10.405
Erucin,	$(C_{21}H_{41}COO)_3C_3H_5$	96.390	8.743
Linolin,	$(C_{17}H_{31}COO)_3C_3H_5$	95.674	10.476
Linolenin,	$(C_{17}H_{29}COO)_3C_3H_5$	95.644	10.549
Clupanodonin,	$(C_{17}H_{27}COO)_3C_3H_5$	95.614	10.623
Ricinolein,	$(C_{17}H_{32}.OH.COO)_3C_3H_5$	95.925	9.869
Dihydroxystearin,	$(C_{17}H_{33}(OH)_2COO)_3C_3H_5$	96.148	9.329

Free Fatty Acids. — The acid number (a) can be readily converted into percentage of free fatty acids (A) expressed as oleic, as sulfuric anhydride (SO_3), as an assumed acid with a molecular weight determined by formula (4), or as the acid of any other molecular weight (m_3).

$$A = \frac{a \times m_3}{56108} \qquad (15)$$

When the free acid or the predominant acid in a mixture is known it is often desirable to report acidity in terms of that acid. In such cases it is preferable to calculate the percentage directly from the titration by factor .0001 of the molecular weight of the acid (monobasic) for an N/10 solution, or .001 for N.

The percentage of acidity (A) can also be calculated from the acid number (a) and the neutralization number (n) of the total fatty acids.[1]

$$A = \frac{a}{n} \qquad (16)$$

The percentage of free fatty acids can be *estimated* approximately from the acid number (a) and saponification number (s): —

$$A = \frac{a}{s}$$

Neutral Fat and Unsaponifiable Matter. — The percentage of neutral fat and unsaponifiable matter can be determined by difference, — 1.00 minus per cent. of free fatty acids.

Neutral Fat and Free Fatty Acids. — The percentage of neutral fat (N) and free fatty acids (A) can be estimated from the ether number (e) by assuming an average saponification number (k) for the neutral product as basis for the calculation.

$$N = \frac{e}{k}$$

$$A = 1.00 - N$$

SOLUBLE FATTY ACIDS.

The soluble fatty acids in an oil, fat or wax indicate the percentage of fatty acids that is soluble in water.[2]

The percentage of soluble fatty acids can be readily calculated by difference, — total fatty acids less the insoluble. It is unnecessary to make the actual determination in most instances. When desired for some particular purpose, however, the test may be carried out as follows: —

Reagents. — Alcohol: redistilled, free from acids and aldehydes.

Alcoholic potash solution: 50 cubic centimeters of a saturated solution of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of alcohol. The alkali should be added to the alcohol slowly, with agitation, in order to prevent any appreciable rise in temperature. The solution should be allowed to stand at least twenty-four hours and filtered immediately before use.

N/2 sulfuric acid.

N/2 potassium (or sodium) hydroxide.

Phenolphthalein solution: 1 gram to 100 cubic centimeters of alcohol, neutralized.

Method. — Five grams of fat are brought into a 300 cubic centimeter Erlenmeyer flask, together with 50 cubic centimeters of alcoholic potash, accurately measured with a burette, and 50 cubic centimeters of alcohol. The flask is connected with a spiral or other form of reflux condenser and the solution boiled on a water bath with occasional rotation until saponification is complete, — about sixty minutes. The condenser is then removed and the flask placed in a water bath (immersed in the water) and the alcohol evaporated at a gradually increasing temperature, care being taken to prevent spattering. The last traces of alcohol, occluded in the soap, are expelled by breaking up the dry cake or by dissolving it in water and continuing the heating. Water to a volume of 100 cubic centimeters and 1 cubic centimeter of N/2 sulfuric acid in excess of that required to neutralize the 50 cubic centimeters of alcoholic potash are added, and the flask, connected with a spiral condenser, heated on a water bath until the separated fatty acids and underlying liquid become clear. From this point the process is conducted the same as for insoluble acids, using a spiral condenser to prevent loss of volatile acids. The combined filtrate and washings are titrated with N/2 potassium hydroxide, using phenolphthalein as indicator. The difference between the titration of the test and that of the excess N/2 acid (1 cubic centimeter) is the alkali equivalent of the soluble acids in the fat taken, which should be calculated to milligrams of potassium hydroxide for 1 gram of fat.

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[1] Strictly it should be the neutralization number of the free fatty acids. The number of cubic centimeters of N alkali required can be substituted in place of the values a and n.

[2] This may mean either hot or cold water, according to the method employed.

1 cubic centimeter of N/2 alkali is equivalent to 28.054 milligrams of potassium hydroxide.

The percentage of soluble fatty acids (S) is calculated from the number of milligrams of potassium hydroxide (k) required to neutralize the soluble acids in 1 gram of fat and the determined (or estimated) neutralization number (n) of the soluble acids by the formula —

$$S = \frac{k}{n}$$

Limit of error, 0.25 per cent.

Supplementary Notes. — The solubility of acids of the acetic series decreases with the increase in number of carbon atoms in the molecule. The so-called "soluble" acids include capric and all acids of less carbon atoms.

Acid.	Soluble in 100 Parts of Water.	
	15° C.	100° C.
Acetic (very soluble),[1]	∞	∞
Butyric (very soluble),	∞	∞
Valeric (soluble),	3.70	–
Caproic (difficultly soluble),	.882	–
Caprylic (insoluble),	.079	.25
Capric (insoluble),	–	.10

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[1] Solubility based on Mulliken's classification, Identification of Pure Organic Compounds, 1, p. 38 (1911): —

	One Gram in —	Grams in 100 c. c.
Very soluble,	5 c. c.	20
Easily soluble,	5– 20 c. c.	20–5
Soluble,	20– 50 c. c.	5–2
Difficultly soluble,	50–150 c. c.	2–.66
Very difficultly soluble,	150–500 c. c.	.66–.2
Insoluble,	500 c. c. and over.	.2 and under.

Lauric is classed as "insoluble," although slightly soluble in boiling water.

A soluble dibasic acid occurs in Japan wax which is not volatile.

Neutralization Number. — The neutralization number indicates the number of milligrams of potassium hydroxide required to neutralize 1 gram of soluble fatty acids.

The difference between the saponification number (s) of the fat and the product of the percentage of insoluble fatty acids (I) times their neutralization number (n_1) indicates the milligrams of potassium hydroxide required to neutralize the soluble fatty acids in 1 gram of fat, which, divided by the percentage of soluble fatty acids (S), gives the neutralization number (n) of the soluble fatty acids.

$$n = \frac{s - In_1}{S}$$

Mean Molecular Weight. — The molecular weight (m) of the soluble fatty acids can be calculated from the neutralization number (n) by means of the formula —

$$m = \frac{56108}{n}$$

Neutralization Numbers of Soluble Fatty Acids.

Acid.	Formula.	Molecular Weight.	Neutralization Number.
Acetic,	CH_3COOH	60.032	934.635
Butyric,	C_3H_7COOH	88.064	637.128
Valeric,	C_4H_9COOH	102.080	549.647
Caproic,	$C_5H_{11}COOH$	116.096	483.290
Caprylic,	$C_7H_{15}COOH$	144.128	389.293
Capric,	$C_9H_{19}COOH$	172.160	325.906

Glycerides of Soluble Fatty Acids. — The percentage of triglycerides (Sg) can be calculated from the percentage (S) and molecular weight (m) of the soluble fatty acids by the formula —

$$Sg = \frac{3\,m + 38.016}{3\,m} \times S$$

Glycerol in the Glycerides of Soluble Acids. — The percentage of glycerol (G) in the glycerides of soluble acids can be calculated from the percentage (S) and molecular weight (m) of the soluble acids: —

$$G = \frac{92.064}{3\,m} \times S$$

See derivation of formula (14) and table "Percentage of Fatty Acids and Glycerol in Triglycerides."

Mean Molecular Weight and Saponification Number of the Glycerides of Soluble Acids. — The mean molecular weight (m_2) and saponification number (s_2) of the glycerides of the soluble acids can be calculated from the molecular weight (m) of the soluble acids: —

$$m_2 = 3\,m + 38.016$$

$$s_2 = \frac{3 \times 56108}{m_2}$$

See table "Saponification Number of Triglycerides."

From the above formulas factors were deduced for the soluble acids enumerated below, by means of which the percentage of triglycerides and of glycerol may be calculated readily from the percentage of fatty acids.

Acid.	Factor for Per Cent. of Triglycerides.	Factor for Per Cent. of Glycerol.
Acetic,	1.21109	.51119
Butyric,	1.14390	.34847
Valeric,	1.12414	.30063
Caproic,	1.10915	.26433
Caprylic,	1.08792	.21292
Capric,	1.07361	.17825

Reichert-Meissl Number.

The Reichert-Meissl number[1] indicates the number of cubic centimeters of N/10 potassium hydroxide required to neutralize that portion of the volatile fatty acids which is obtained from 5 grams of an oil, fat or wax by the Reichert distillation process.[2]

Reagents. — Glycerol potash solution: 120 grams of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of pure glycerol, heated sufficiently to dissolve the alkali (about 115° C.).

Sulfuric acid: 1 to 4.

N/10 potassium (or sodium) hydroxide.

Phenolphthalein solution: 1 gram to 100 cubic centimeters of alcohol, neutralized.

Method. — Into an Erlenmeyer flask of 300 cubic centimeters capacity are brought 5 grams of fat, care being taken to avoid getting any fat on the sides of the flask, together with 20 cubic centimeters of glycerol potash, heated over a small naked flame and rotated continuously until the saponification is complete, as shown by the solution becoming perfectly clear. Care should be taken not to overheat and discolor the material. The soap when cold should be absolutely free from globules of fat. Ten grams of glass beads,[1] 135 cubic centimeters of recently boiled distilled water, and 5 cubic centimeters of sulfuric acid (1 to 4) are added, and the flask connected with a Liebig condenser.[2] (See Fig. 3.) The mixture is heated on 16-mesh Ni-chrome wire gauze at low ebullition, until the separated fatty acids and underlying liquid become *clear*. One hundred and ten cubic centimeters are then distilled as nearly as possible in thirty minutes, and received in a graduated flask. The flame should be well oxidized to induce vigorous agitation of the beads, thus assuring a more thorough separation of the volatile acids. The distillate is thoroughly mixed and passed through a dry, dense filter to remove all traces of higher fatty acids that appear as oily drops or white solid particles. One hundred cubic centimeters are pipetted into an Erlenmeyer flask and titrated with N/10 alkali, using 1 cubic centimeter[3] of phenolphthalein as indicator, avoiding entirely the addition of water. The pink coloration should hold several minutes. Care should be exercised at all times during the process to prevent the absorption of carbonic acid. Blank determinations should be run with every new lot of reagents. The titration reading,

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[1] The Reichert-Meissl number is about 2.2 times as great as the Reichert. — Lewkowitsch, Analysis of Oils, Fats and Waxes, 1, p. 417, (1913).

[2] Ztschr. Analyt. Chem. 18, pp. 68–73 (1879).

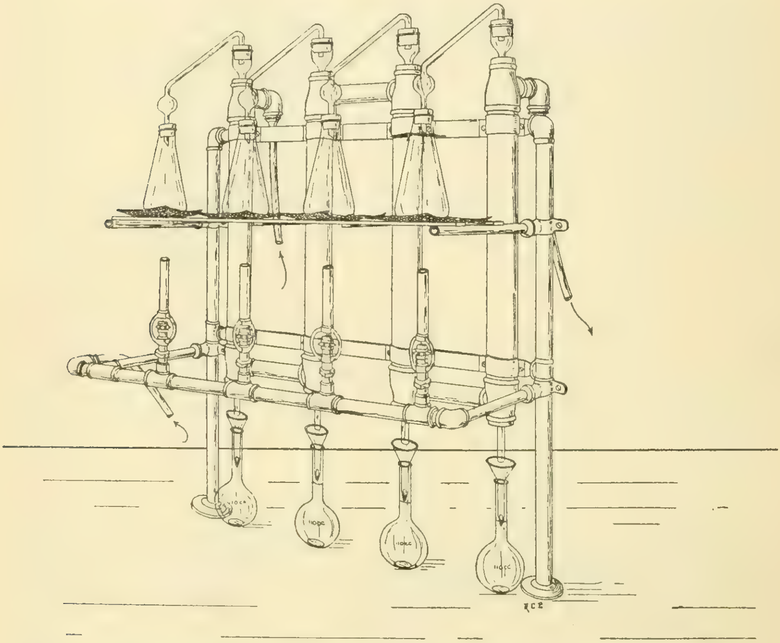

FIG. 3. — Distillation apparatus employed in the determination of Reichert-Meissl number.

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[1] Weighing approximately one-half gram each.

[2] A vertical condenser with a rapid circulation of cold water is preferable.

[3] A definite quantity is necessary if the mean molecular weight is to be determined.

multiplied by 1.1, minus the blank, and reduced to a 5-gram fat basis, is the Reichert-Meissl number.

Limit of error, 0.25 cubic centimeter.

Synopsis of Reaction.

$$\underset{\text{fat}}{(RCOO)_3C_3H_5} + \underset{\text{alkali}}{3\ KOH} = \underset{\text{salt}}{3\ RCOOK} + \underset{\text{glycerol}}{C_3H_5(OH)_3}$$

The glycerol acts as a transmitter of heat, having a boiling point of 290° C.

$$2\ RCOOK + H_2SO_4 = 2\ RCOOH + K_2SO_4$$

Distillation of the volatile acids. Titration.

Supplementary Notes. — As this method is only an arbitrary one it is essential to adhere strictly to the conditions of operation as laid down if comparative results are to be obtained, and by so doing over 80 per cent. of the soluble acids in butter can be secured in the distillate. Jensen states that the Reichert process[1] yields with butter fat 85 to 88 per cent. of the total butyric, 24 to 25 per cent. of the caprylic, and 85 to 100 per cent. of the capric acids. Repeated distillation yields higher results, but is accompanied by decomposition of the nonvolatile acids. Glycerol potash is preferable to alcoholic potash in that it shortens the process and prevents possible loss due to the formation of esters during saponification. Sodium hydroxide has greater basicity than potassium hydroxide, but the resulting hard soap is less soluble. The fatty acids appear to have practically the same affinity for both hydroxides.

Acetic, butyric, valeric, caproic, caprylic and capric are the only fatty acids that can be distilled under ordinary pressure without decomposition. These acids have comparatively high boiling points, as shown by the following table, but owing to their high vapor tension they can be readily distilled from aqueous solutions with steam, and are termed "volatile" acids: —

ACIDS.	Boiling Point (° C.).
Acetic,	118.1
Butyric,	162.3
Valeric,	186.0–186.4
Caproic,	202.0–203.0
Caprylic,	236.0–237.0
Capric,	268.0–270.0

The boiling points rise with the increase in molecular weight. Lauric acid is very slightly volatile in a current of steam. The nonvolatile acids when distilled at ordinary pressure undergo partial decomposition and yield hydrocarbons of the ethane and possibly other series. In vacuo they can be distilled with or without superheated steam.

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[1] Ztschr. Untersuch. Nahr. u. Genussmtl. 1905, p. 272.

Most of the natural fats and oils contain but a small amount of volatile (soluble) fatty acids, generally below 2 Reichert-Meissl number. Some prominent exceptions have already been enumerated, being characterized by saponification numbers exceeding 210. See supplementary notes under "Saponification Number." The high Reichert-Meissl numbers of dolphin and porpoise oils may be due to valeric acid. The amount of volatile or soluble acids in those oils and fats whose saponification number does not exceed 195 is inappreciable.

Among the oils and fats with a high volatile acid content might be mentioned[1] myrtle seed oil, croton oil, oleander oil, senega root oil, lycopodium oil, apeiba oil, dolphin oil, macassar oil, muriti fat, mocaya oil, palm kernel oil, coconut oil and tonka butter, having Reichert-Meissl numbers between 5 and 15; and spindle tree oil, malukang oil, dolphin jaw oil, porpoise body oil, porpoise jaw oil, brown fish oil and butter fat, having Reichert-Meissl numbers ranging from 25 to 50, or even greater in some instances.

The amount of volatile acids is likely to increase with the age of the sample.

The results of Wechsler[2] and other investigators indicate that volatile acids of higher molecular weight distill over before the lower acids, especially in cases where the neutrality of the solution is destroyed gradually by several additions of acid instead of one, thus fractionating the distillates.

Neutralization Number and Mean Molecular Weight. — The titrated volatile acids[3] resulting from the determination of the Reichert-Meissl number are evaporated in a tared platinum dish and dried to constant weight in an oven at 100° C. From the weight (w) of the salts and the quantity (v) of N/10 alkali used, the mean molecular weight (m) and the neutralization number (n) can be calculated by the formulas —

$$\mathrm{RCOONa} - \mathrm{Na} + \mathrm{H} = \mathrm{RCOOH}$$

$$m = \frac{40.008\ (w - .0021992\ v)}{.0040008\ v}$$

$$m = \frac{10000\ (w - .0021992\ v)}{v}$$

$$n = \frac{56108}{m}$$

Blank determinations should be run with every new lot of reagents, both by distillation (Reichert-Meissl number) and by evaporation of the titrated portion (salts), and deducted in the calculation.

Limit of error, 1 unit molecular weight.

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[1] Lewkowitsch, Analysis of Oils, Fats and Waxes, 1, p. 423 (1913).

[2] Jour. Soc. Chem. Indus., 1894, p. 179. (From Lewkowitsch.)

[3] Using N/10 sodium hydroxide, prepared from caustic alkali that is free from carbonate and other impurities. The solution should be filtered frequently to remove silica arising from decomposition of the glass.

Volatile Acids.

The percentage of volatile acids (V) can be calculated from the weight (w) of the salts obtained, the quantity (v) of N/10 alkali used (as shown above), and the weight (w_1) of fat taken for the Reichert-Meissl determination by the formula —

$$V = \frac{1.1\ (w - .0021992\ v)}{w_1}$$

The percentage of volatile acids (V) can be calculated in a like manner from the Reichert-Meissl number and the neutralization number (n) of the volatile acids by the formula —

$$V = \frac{0.2\ \text{R-M. No.}\ \times 5.6108}{n}$$

Formulas for calculating the amount of *triglycerides* of the volatile fatty acids, the *mean molecular weight* and *saponification number* of the triglycerides, and *glycerol* content will be found under like headings of "Soluble Acids."

Polenske Number.

The Polenske number indicates the number of cubic centimeters of N/10 potassium hydroxide required to neutralize that portion of the insoluble volatile acids which is obtained from 5 grams of an oil, fat or wax by the Reichert distillation process.

Reagents. — Glycerol potash solution: 120 grams of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of pure glycerol, heated sufficiently to dissolve the alkali (about 115° C.).

Sulfuric acid, 1 to 4.

Alcohol: redistilled, free from acids and aldehydes.

N/10 potassium (or sodium) hydroxide.

Phenolphthalein solution: 1 gram to 100 cubic centimeters of alcohol, neutralized.

Cotton blue 6B solution: 2 grams to 100 cubic centimeters of alcohol. The indicator should be boiled in a flask under a reflux condenser for two hours and then filtered.

Method. — The method can be conducted in connection with the Reichert-Meissl test, and may be considered supplementary to it. A vertical condenser should be employed with a circulation of water adequate to chill the distillate to 20° C., and the test carried out as usual. The resulting distillate is chilled fifteen minutes at 15° C., carefully mixed by reversing the flask several times (avoiding any shaking), and poured through a dry 11 centimeter filter. The condenser, 110 cubic centimeter flask and filter are washed three times in succession with 15 cubic centimeter portions of water to remove soluble acids, and the wash waters thrown away. The insoluble volatile acids in the condenser, 110 cubic centimeter flask and filter are dissolved in alcohol and titrated with N/10 alkali, using 1 cubic centimeter of phenolphthalein as indicator. The titration reading minus the blank, reduced to a 5-gram basis, is the Polenske number.

Limit of error, 0.10 cubic centimeter.

Synopsis of Reaction. — Solution of insoluble volatile acids in alcohol. Titration.

Supplementary Notes. — The Polenske number for most oils and fats having a saponification number of about 195 rarely exceeds .65, unless the product is excessively acid or rancid.[1] The Polenske number of butter fat is about 2 to 3, of palm kernel oil, 10 to 12, and of coconut oil, 15 to 20.

INSOLUBLE FATTY ACIDS AND UNSAPONIFIABLE MATTER (HEHNER NUMBER).[2]

The insoluble fatty acids in an oil, fat or wax indicate (unless otherwise stated) the percentage of fatty acids and unsaponifiable matter that is insoluble in water.[3]

Reagents. — Glycerol potash solution: 120 grams of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of pure glycerol, heated sufficiently to dissolve the alkali (about 115° C.).

Sulfuric acid: 1 to 4.

Ceresine: pure white, filtered.

Ethyl ether: anhydrous and free from alcohol and residue.

Method. — Five grams of fat are brought into a 300 cubic centimeter Erlenmeyer flask, together with 20 cubic centimeters of glycerol potash, and heated over a small naked flame, rotating continuously until the saponification is complete, as shown by the solution becoming perfectly clear. Care should be taken not to overheat and discolor the material. The resulting soap, absolutely free from globules of fat, is dissolved in 150 cubic centimeters of hot water and decomposed with a slight (few drops) excess of sulfuric acid (1 to 4).[4] The flask is heated on a water bath with occasional agitation, until the separated fatty acids and underlying liquid become clear. This requires a number of hours, generally overnight, and must not be slighted. The flask is immersed in cold water[5] to solidify the fatty acids, after which the solution is decanted through a dense, ether-extracted filter,[6] care being taken not to break the insoluble cake. One hundred and fifty cubic centimeters of boiling water are added, thoroughly agitated, heated as above, cooled and decanted, the process being repeated until the washings are free from acid. Litmus paper is not sufficiently sensitive for this purpose. The final 150 cubic centimeters of filtrate should give a decided color with three or four drops of N/10 alkali, using phenolphthalein as indicator. In those cases where caprylic and particularly capric acids are present the filtrate may give an appreciable acid reaction after 10 to 15 washings. The treatment should be continued until the acidity of the filtrate is less than 0.25 cubic centimeter N/10 solution.

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[1] Lewkowitsch, Analysis of Oils, Fats and Waxes, 1, p. 426 (1913).

[2] Angell and Hehner, Butter: Its Analysis and Adulteration (1874).

[3] This may mean either hot or cold water, according to the method employed.

[4] About 5 cubic centimeters are required.

[5] A flat-bottomed "plug" sink with the outlet closed with a perforated cork, carrying a piece of glass tubing to regulate the height of the water, serves quite satisfactorily as a chilling bath.

[6] Baker & Adamson Chemical Company, 12.5 centimeters washed filter paper, "B" dense.

In determining the insoluble acids of oils and fats having a low solidifying point, the addition of .5 to 1 gram of ceresine[1] before treating with sulfuric acid greatly facilitates subsequent work, and serves to protect the unsaturated acids from decomposition.

The filter and inverted flask containing the cake of insoluble fatty acids are allowed to drain in a cool place until practically dry. A convenient filter stand for both filtration and draining is illustrated by Wiley.[2] The small particles of fat adhering to the filter are dissolved in ether in a continuous fat extractor[3] run into the flask, and the ether expelled in the usual manner. The ether fumes are very persistent and necessitate blowing out the flask with hand bellows. The insoluble acids are dried in an oven at 100° C., or in a vacuum oven at 70° C., to approximately constant weight. At 100° C. the drying periods should not exceed two hours. The weight of the flask is determined at the completion of the test, to offset the solvent action of the reagents on the glass. Blanks should be run on every new lot of ceresine to determine the amount (if any) of soluble material present.

There are compensating errors that usually result from this method, namely, volatilization of fatty acids, dehydration of simple and of hydroxy fatty acids with the formation of anhydrides and of lactones, respectively, and oxidation of unsaturated acids.[4] Drying in a vacuum oven at 70° C., in a current of carbonic acid gas or even of dry air, will reduce oxidation as well as dehydration and volatilization.

Limit of error, 0.25 per cent.

Synopsis of Reaction. — Similar to those of Reichert-Meissl number.

Supplementary Notes. — Differences in chemical structure of the insoluble fatty acids permit of their classification into saturated, unsaturated, hydroxy acids, etc.

The principal saturated acids are lauric, myristic, palmitic, stearic, arachic and dihydroxystearic.

The most prominent unsaturated acids are oleic, erucic, linolic, linolenic, clupanodonic and ricinoleic. When these acids are compared with the empirical formula for saturated acids, $C_nH_{2n+1}COOH$, they show a deficiency of 2, 4, 6 or 8 atoms of hydrogen, which indicates their power to absorb iodine chloride with the formation of additive compounds.

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[1] The amount required varies with the consistency of the insoluble acids that are being determined.

[2] Foods and Food Adulterants, U. S. Dept. Agr., Bur. Chem., Bul. 13, p. 457.

[3] See Fig. 4, page 136.

[4] Saturated acids do not readily absorb oxygen. Unsaturated acids of the linolic and linolenic series absorb oxygen from the air at ordinary temperatures, and of the oleic series at higher temperatures.

Members of the chaulmoogric and tariric series constitute an exception to the above statement. (See "Calculated Data from the Iodine Number.") Unsaturated acids containing an open chain of 18 carbon atoms (oleic, linolic, linolenic acids, etc.) are reduced by hydrogen in the presence of a suitable catalyzer (nickel or colloidal palladium) to stearic acid.

Dihydroxystearic and ricinoleic acids are hydroxy acids which on acetylation assimilate an acetyl radical (CH_3CO) in place of the hydrogen in every alcoholic hydroxyl group.

Most fats and oils contain from 93 to 96 per cent. of insoluble acids, with a mean of approximately 95. Some notable exceptions, having saponification numbers exceeding 210 and a high volatile acid content, have already been mentioned. The fatty acids are practically all insoluble where the saponification number of an oil or fat does not exceed 195. Croton oil contains about 89 per cent. of insoluble acids and unsaponifiable matter; dolphin jaw oil, 66 per cent.; porpoise jaw oil, 70 per cent.; brown fish oil, 85.5 per cent.; laurel oil, 83.5 to 87 per cent.; palm nut oil, 87.5 to 91 per cent.; coconut oil, 88.5 to 90 per cent.; Japan wax, 90.5 per cent.; and butter fat, 86.5 to 90 per cent.

In liquid waxes the amount of insoluble fatty acids free from alcohols and hydrocarbons varies from 60 to 65 per cent., and in solid waxes from 47 to 60 per cent.

The acid content of palmitin is 95.29, stearin 95.73, olein 95.70, linolein 95.67 and linolenin 95.64 per cent.; therefore the percentage of insoluble acids in most oils and fats free from appreciable amounts of the lower fatty acids and of unsaponifiable matter must be in the vicinity of 95.

Preparation of Insoluble Acids.

The method for preparing insoluble fatty acids for analysis is the same as described for the determination of "Insoluble Acids," with the elimination of such features as are necessary only for quantitative work. About 28.5 cubic centimeters (25 grams) of the melted fat or oil are pipetted into a 750 cubic centimeter Erlenmeyer flask, together with 100 cubic centimeters of glycerol potash, and saponified. The resulting soap is dissolved in 500 cubic centimeters of hot water, decomposed with a slight excess (few drops) of sulfuric acid (1 to 4), and heated on a water bath, with occasional agitation, until the separated fatty acids and underlying liquid become clear. Several such charges will furnish sufficient material for the analysis. The fatty acids may be washed as described under "Insoluble Acids," or the contents of the flasks transferred to a separatory funnel and washed by shaking out with hot water,[1] until free from soluble acids. The latter modification has some advantages, particularly for insoluble acids of low melting point. Thorough washing may not always insure the entire removal of caprylic and capric acids when present, but the treatment should not be unduly prolonged for fear of injury to the unsaturated acids. The melted fatty acids are run into a test tube, heated in a water bath at 60° C. to allow any water present to settle out, filtered in a jacketed funnel, and preserved in a well-stoppered bottle in a cool dark place. The above process should yield fatty acids practically free from decomposition. It is inadvisable to employ the residue from the quantitative determination of the insoluble acids for further tests.

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[1] The layer of fatty acids should be allowed to partially solidify at least, before the water is drawn off, to insure conditions similar to those prevailing in the quantitative determination of the insoluble acids.

Neutralization Number.

The neutralization number indicates the number of milligrams of potassium hydroxide required for the complete neutralization of 1 gram of insoluble fatty acids by the saponification process.

Reagents. — Alcohol: redistilled, free from acids and aldehydes.

Alcoholic potash solution: 50 cubic centimeters of a saturated solution of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of alcohol. The solution should be allowed to stand at least twenty-four hours and filtered immediately before use.

N/2 hydrochloric acid.

Phenolphthalein solution: 1 gram to 100 cubic centimeters of alcohol, neutralized.

Cotton blue 6B solution: 2 grams to 100 cubic centimeters of alcohol. The indicator should be boiled in a flask under a reflux condenser for two hours and then filtered.

Method. — Into a 300 cubic centimeter Erlenmeyer flask are brought 5 grams of insoluble fatty acids, together with 50 cubic centimeters of alcoholic potash accurately measured with a burette, 50 cubic centimeters of alcohol and several glass beads. The flask is then connected with a spiral or other form of reflux condenser and the solution boiled on a water bath with occasional rotation until the reaction is complete, — about sixty minutes. The flask is then placed in a water bath at 60° C., and the solution, after cooling to that temperature, titrated with N/2 hydrochloric acid, using 1 cubic centimeter of phenolphthalein or cotton blue as indicator. For further details see "Saponification (Koettstorfer) Number." The difference between the titration of the blank and that of the excess alkali of the test is the acid equivalent of the insoluble acids taken, which should be calculated to milligrams of potassium hydroxide for 1 gram of insoluble acids. In all cases where the unsaponifiable matter constitutes an appreciable amount it should be deducted in calculating the neutralization number of the insoluble fatty acids, and so stated.

1 cubic centimeter of N/2 acid is equivalent to 28.054 milligrams of potassium hydroxide.

Limit of error, 0.50 milligram.

Synopsis of Reaction. — See "Acid Number" with titration of excess alkali, as in "Saponification Number."

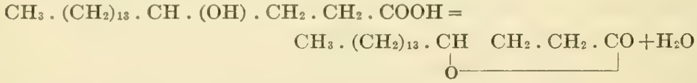
Mean Molecular Weight. — The molecular weight (m) of the insoluble fatty acids can be calculated from the neutralization number (n) by means of the formula —

$$m = \frac{56108}{n}$$

or directly from the acid equivalent (v) and weight (w) of insoluble fatty acids taken: —

$$m = \frac{2000\ w}{v}$$

Supplementary Notes. — Direct titration of the fatty acids in alcohol with N/2 alkali in a manner similar to that of "Acid Number" is often recommended, although the process tends to yield low neutralization numbers,[1] probably due to the presence of lactones (inner anhydrides of hydroxy acids) or of anhydrides of simple fatty acids, which do not combine with aqueous alkali in the cold, but readily hydrolyze on boiling with alcoholic potash. The lactones and anhydrides may result from drying under unfavorable conditions. Marked differences between the two methods are shown in the references cited. In our hands, working with purified insoluble fatty acids, only slight differences were obtained except in the case of oleic acid. The saturated acids were prepared with special precautions and dried at a low temperature, which precluded the possibility of forming anhydrides. Hydroxy acids, such as ricinoleic acid of castor oil, are particularly likely to dehydrate with the formation of inner anhydrides. Lactones occur naturally or are readily formed from the fatty acids of Sewarri fat and of wool wax. In the latter case they result to some extent from heating at 100° C. The fatty acids of castor oil polymerize on long standing even at ordinary temperature to polyricinoleic acid. Gamma hydroxystearic acid on losing a molecule of water forms stearolactone, and may serve as an example (Lewkowitsch): —



$$CH_3 \cdot (CH_2)_{13} \cdot CH \cdot (OH) \cdot CH_2 \cdot CH_2 \cdot COOH =$$
$$CH_3 \cdot (CH_2)_{13} \cdot \underset{\underset{O}{|}}{CH}\quad CH_2 \cdot CH_2 \cdot \underset{|}{CO} + H_2O$$

The neutralization numbers of the mixed insoluble acids of most vegetable and animal oils and fats range from 185 to 215, averaging about 200, with the exception of the vegetable fats of the myristica, coconut oil and dika fat groups which range from about 252 to 271.

The neutralization numbers of the mixed insoluble acids of some of the more prominent oils and fats are linseed oil, 200; corn oil, 200; cottonseed oil, 205; sesame oil, 200; rape oil, 185; peanut oil, 202; olive oil, 201; castor oil, 192; cod liver oil, 205; palm oil, 207; cacao butter, 190; palm nut oil, 261; coconut oil, 271; lard, 205; beef tallow, 208; and butter fat, 215 to 225. These figures are reasonably accurate in most instances.

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[1] Tortelli and Pergami, Chem. Rev. Fett u. Harz Indus., 9, pp. 182, 204 (1902); Lewkowitsch, Analysis of Oils, Fats and Waxes, 1, pp. 518, 519 (1913).

Neutralization Number of Insoluble Fatty Acids.

ACID.	Formula.	Molecular Weight.	Neutralization Number.
Lauric,	$C_{11}H_{23}COOH$	200.192	280.271
Myristic,	$C_{13}H_{27}COOH$	228.224	245.846
Palmitic,	$C_{15}H_{31}COOH$	256.256	218.953
Stearic,	$C_{17}H_{35}COOH$	284.288	197.363
Arachic,	$C_{19}H_{39}COOH$	312.320	179.649
Oleic,	$C_{17}H_{33}COOH$	282.272	198.773
Erucic,	$C_{21}H_{41}COOH$	338.336	165.835
Linolic,	$C_{17}H_{31}COOH$	280.256	200.203
Linolenic,	$C_{17}H_{29}COOH$	278.240	201.653
Clupanodonic,	$C_{17}H_{27}COOH$	276.224	203.125
Ricinoleic,	$C_{17}H_{32}.OH.COOH$	298.272	188.110
Dihydroxystearic,	$C_{17}H_{33}(OH)_2COOH$	316.288	177.395

Glycerides of Insoluble Fatty Acids. — The percentage of triglycerides (Ig) can be calculated from the percentage (I) and molecular weight (m) of the insoluble fatty acids by the formula —

$$Ig = \frac{3\,m + 38.016}{3\,m} \times I$$

Glycerol in the Glycerides of Insoluble Acids. — The percentage of glycerol (G) in the glycerides of insoluble acids can be calculated from the percentage (I) and molecular weight (m) of the insoluble acids: —

$$G = \frac{92.064}{3\,m} \times I$$

See derivation of formula (14) and table "Percentage of Fatty Acids and Glycerol in Triglycerides."

Mean Molecular Weight and Saponification Number of the Glycerides of Insoluble Acids. — The mean molecular weight (m_1) and saponification number (s_1) of the glycerides of the insoluble acids can be calculated from the molecular weight (m) of the insoluble acids: —

$$m_1 = 3\,m + 38.016$$

$$s_1 = \frac{3 \times 56108}{m_1}$$

See table "Saponification Number of Triglycerides."

From the above formulas factors were deduced for the insoluble acids enumerated below, by means of which the percentage of triglycerides and of glycerol may be readily calculated from the percentage of fatty acids: —

Acid.	Factor for Per Cent. of Triglycerides.	Factor for Per Cent. of Glycerol.
Lauric,	1.06330	.15329
Myristic,	1.05552	.13446
Palmitic,	1.04945	.11976
Stearic,	1.04457	.10795
Arachic,	1.04057	.09826
Oleic,	1.04489	.10872
Erucic,	1.03745	.09070
Linolic,	1.04522	.10950
Linolenic,	1.04554	.11029
Clupanodonic,	1.04588	.11110
Ricinoleic,	1.04248	.10289
Dihydroxystearic,	1.04006	.09703

Lactones and Anhydrides.

The amount of lactones and anhydrides present in the separated insoluble acids of oils and fats can be measured in terms of milligrams of potassium hydroxide by the difference in the amount of alkali required to titer (neutralize) the acids in cold alcohol and that absorbed on saponifying with alcoholic potash. Lactones and anhydrides are unable to combine with alkali until transformed into acids. They are not hydrolyzed to any considerable extent in cold alcohol, but are readily hydrolyzed by boiling alcoholic potash.

Reagents. — Same as for "Acid" and "Saponification" numbers.

Method. — Five grams of insoluble fatty acids are brought into a 300 cubic centimeter Erlenmeyer flask, together with 100 cubic centimeters of alcohol, and titrated in the cold with N/2 potassium hydroxide, using 1 cubic centimeter of phenolphthalein or cotton blue as indicator. An additional 5 grams of insoluble acid are brought into a flask and treated exactly as described for saponification number. The difference between the two determinations, in terms of milligrams of potassium hydroxide to the gram of insoluble acids, measures the amount of lactones and anhydrides present. The same weight of fat may serve for both determinations if desired.

Limit of error, same as in the determinations of acid and saponification numbers.

Synopsis of Reaction. — Solution in alcohol.

Neutralization: —

$$\underset{\text{acid}}{RCOOH} + \underset{\text{lactone}}{ROCO} + \underset{\text{anhydride}}{(RCO)_2O} + KOH = RCOOK + ROCO + (RCO)_2O + H_2O$$

Saponification: —

$$RCOOH + ROCO + (RCO)_2O + 4\ KOH$$
$$= RCOOK + R\ .\ OH\ .\ COOK + 2\ RCOOK + 2\ H_2O$$

When the lactone or anhydride in the insoluble acids, or the predominant one in a mixture, is known, the percentage (L) can be calculated from the determined alkali equivalent[1] (l), — *i.e.*, saponification number less acid number of insoluble acids, and the theoretical saponification number (k) of the lactone or anhydride, — by the formula —

$$L = \frac{l}{k}$$

Iodine Number.

The iodine number indicates the percentage of iodine chloride absorbed under definite conditions by the insoluble fatty acids, expressed in terms of iodine.

See method for oils and fats.

The iodine number of insoluble acids does not necessarily correspond to that of the natural oil, fat or wax from which the acids were derived. This is said to be due to the influence of soluble fatty acids in the natural product, although it is probable that in the process of separation some decomposition of the unsaturated acids results.

Insoluble acids after titration with thiosulfate undergo a reversible reaction and split off iodine much more rapidly than the oils and fats from which they were derived.

Acetyl Number.

The acetyl number indicates the number of milligrams of potassium hydroxide required to combine with the acetyl absorbed by 1 gram of insoluble fatty acids on acetylation.

See method for oils and fats.

The acetylated product should be washed until the acidity of the filtrate (150 cubic centimeters) is less than 0.25 cubic centimeter N/10 solution.

Stearic Acid.

The stearic acid indicates the percentage of that acid in the insoluble fatty acids of an oil or fat.

Reagents. — Alcoholic-stearic solution: 3 grams of crystalline stearic acid of theoretical molecular weight to 1,000 cubic centimeters of purified alcohol[1] of about 95.25 per cent., heated sufficiently to give a clear solution.

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[1] Lactone number.

Ethyl ether: free from residue.

Apparatus. — Eight-ounce sterilizer bottles[2] of narrow cylindrical form ($6\frac{3}{4}$ by 2 inches).

Small thistle tubes ($\frac{1}{4}$-inch bulb) with a felt of absorbent cotton, weighing .02 gram, supported by a glass bead and covered by a piece of cheesecloth.

Ice tank of $\frac{7}{8}$-inch material (approximately 20 inches long, 10 inches wide and 20 inches deep), lined with galvanized iron, provided with a tight cover, and supported by legs to a convenient working height.

For icing, a basket ($13\frac{1}{2}$ by 6 by 18 inches) of galvanized screening of $\frac{5}{16}$-inch mesh.

Pockets of galvanized screening to support the bottles so that only a small portion of the neck projects out of the ice water.

A pump or agitator run by motor to keep the water in continuous circulation.

Method. — Five-tenths of a gram of melted insoluble acids are brought into an 8-ounce sterilizer bottle, and 150 cubic centimeters of an alcoholic-stearic solution, accurately measured with a pipette at 30° C., added. The bottle is sealed with a solid rubber stopper, shaken at a gradually increasing temperature until a clear solution is obtained, immediately placed in a pocket of the ice tank and allowed to stand overnight. The following morning the solution is gently agitated by inverting the bottle several times, and in the afternoon is siphoned off as thoroughly as possible by means of a small thistle tube[3] and a perforated rubber stopper, using suction. The residue is dissolved in ethyl ether, transferred to a tared 140 cubic centimeter wide-mouthed Erlenmeyer flask, the ether carefully distilled off, dried at 100° C., and weighed. As saturation may vary somewhat with the amount of stearic acid present, and as the quantity of solution retained by the precipitate depends in a measure on the amount of precipitate, blanks are run on a weight of stearic acid equivalent to that expected in the test. By deducting the additional stearic acid taken, from the weight recovered, the true blank for the alcoholic-stearic solution is obtained.

The molecular weights of the precipitates should be determined occasionally to check the operation. In the presence of palmitic acid it has been found necessary to increase the amount of stearic acid in solution in order to counteract the solvent action of the former acid.

Limit of error, from 0.50 to 0.75 per cent.

Synopsis of Reaction. — Solution of insoluble fatty acids in alcoholic-stearic solution.

Crystallization of stearic acid under control conditions.

Filtration.

Recovery and weight of precipitate.

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[1] See "Reagents," under "Saponification Number."

[2] Manufactured by Whitall Tatum Company, Philadelphia, Pa.

[3] The size of the tube and preparation of the felt have already been described.

IODINE NUMBER.

The iodine number indicates the percentage of iodine chloride absorbed under definite conditions by an oil, fat or wax, expressed in terms of iodine.

Reagents. — Iodine solution according to Wijs.[1] Thirteen grams of resublimated iodine to 1,000 cubic centimeters of acetic acid[2] (99.5 per cent.), free from oxidizable products. After the iodine is completely dissolved the solution is treated with pure dry chlorine gas[3] until the iodine has been converted into monochloride. The completion of the reaction is indicated by a distinct change, the solution becoming transparent cherry red, and its titer[4] with thiosulfate doubled. As it is advisable to have a slight excess of iodine, a small quantity of untreated solution should be retained and may be added in case of necessity.

N/10 sodium thiosulfate (hyposulfite) solution: 24.822 grams[5] of sodium thiosulfate, dissolved in water and made up to a liter.

Potassium bichromate solution: 3.8633 grams of dry C. P. potassium bichromate, free from sodium bichromate, dissolved in water and made up to a volume of 1,000 cubic centimeters at 20° C. This solution will keep almost indefinitely without changing, and is used for standardizing the thiosulfate solution. One hundred cubic centimeters of potassium bichromate will liberate 1 gram of iodine from a potassium iodide solution.

Potassium iodide solution: 165 grams of neutral potassium iodide, free from iodine and iodate, to 1,000 cubic centimeters of water. Iodate is said to be present frequently in commercial potassium iodide, and yields free iodine with hydrochloric acid.

Starch paste: 1 gram to 200 cubic centimeters of water. The indicator is prepared by boiling thoroughly, decanting and diluting the solution, and again boiling to insure a perfect paste free from solid particles.

Carbon tetrachloride: anhydrous[6] and free from oxidizable products.[7]

Standardizing the Thiosulfate. — Twenty-five cubic centimeters of potassium bichromate are accurately measured with a burette into a 300 cubic centimeter Erlenmeyer flask, and 10 cubic centimeters of potassium iodide and 5 cubic centimeters of concentrated hydrochloric acid added. Simultaneously with the addition of the acid, thiosulfate is run in until the brownish yellow color (iodine) has been largely destroyed; then 2 cubic centimeters of starch paste are added and the titration continued with repeated thorough shaking until the blue color has entirely disappeared, leaving a bright green solution. As four times the titration is equivalent to 1 gram of iodine, the iodine value of 1 cubic centimeter of thiosulfate can be readily calculated.

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[1] Ber. Deut. Chem. Gesell. 31, p. 750 (1898). Wijs' solution, with the same active reagent, iodine monochloride, has largely replaced that of Hubl on account of its far greater stability and more rapid absorption.

[2] The acid should be crystallized at 15° C. and the mother liquor discarded. The acid should not react with the bichromate test.

[3] Washed and dried by being passed through concentrated sulfuric acid. Gas sufficient for 4,000 cubic centimeters of iodine solution can be generated from 44.5 grams of sodium chloride, 55.5 grams of manganese dioxide, and 150 cubic centimeters of sulfuric acid (1 to 1).

[4] With the addition of potassium iodide as usual.

[5] Preferably 30 grams to 1,000 cubic centimeters of water.

[6] Dried over recently ignited sodium sulfate and distilled.

[7] Bichromate test.

In theory, 1 cubic centimeter N/10 $Na_2S_2O_35\ H_2O$ is equivalent to .012692 gram of iodine.

The following is the reaction: —

$$K_2Cr_2O_7 + 14\ HCl + 6\ KI = 2\ CrCl_3 + 8\ KCl + 6I + 7\ H_2O$$

$$6I : K_2Cr_2O_7 :: 1 : x$$

$$761.52 : 294.20 :: 1 : 0.38633 \text{ gram in 100 c.c.}$$

Wijs-Hubl Method.[1] — The amount of material to be taken for this determination varies inversely with its iodine number (see table). From 0.30 to 0.45 gram of drying or fish oil, 0.45 to 0.70 gram of a semidrying oil, 0.55 to 0.90 gram of a nondrying oil, or 0.60 to 2 grams of fat are brought into a 300 cubic centimeter Erlenmeyer flask, together with 20 cubic centimeters of carbon tetrachloride. After complete solution, 50 cubic centimeters of iodine solution, accurately measured with a burette, are added and the flask well stoppered and allowed to stand three to four hours, [2] with occasional shaking, in a refrigerator at a temperature below 10° C. A rapid bleaching of the solution indicates insufficient iodine. An excess equal to the amount absorbed is deemed necessary for the attainment of constant results. The cork stopper for the flask should be rolled until soft and pliable, and moistened with potassium iodide to prevent loss of iodine by volatilization. At the end of the absorption period, 50 cubic centimeters of cold, recently boiled distilled water and 10 cubic centimeters of potassium iodide are added to the contents of the flask, and the excess iodine titrated with sodium thiosulfate. The thiosulfate is run in gradually, with constant shaking, until the brownish yellow color of the solution has been largely destroyed; then 2 cubic centimeters of starch paste are added and the titration continued until the blue color has entirely disappeared. Towards the end of the reaction the flask should be stoppered and shaken vigorously, so that any iodine in the carbon tetrachloride will be taken up by the potassium iodide. The "bleached" condition should hold for a considerable time with the flask stoppered, although the blue color will develop again, due to the splitting off of iodine. Several blank determinations should be run with every series of tests. The difference between the titration of the blank and that of the excess iodine is the thiosulfate equivalent of the fat, which multiplied by the factor (obtained as described) and divided by the weight of fat taken gives the percentage of iodine absorbed.

Limit of error, 0.25 per cent.

Synopsis of Reaction. — Solution with carbon tetrachloride.

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[1] Original Hubl method. Dingler's Polytech. Jour., 253, p. 281.

[2] According to Lewkowitsch one-half hour is sufficient for all oils and fats having an iodine number below 100, one hour for semidrying oils and two to six hours for drying oils. — Analysis of Oils, Fats and Waxes, 1, p. 407, (1913).

Formation of chloro-iodo additive compounds with unsaturated acids and their glycerides.

Solution of excess iodine with potassium iodide and titration with thiosulfate, using starch paste as indicator.

$$2I + 2\,Na_2S_2O_3 = Na_2S_4O_6 + 2\,NaI$$

Amount of Material for Different Iodine Numbers.

[50 cubic centimeters of Wijs solution.]

Iodine Number.	Grams of Material.	Iodine Number.	Grams of Material.
200,	.32	100,	.64
195,	.33	95,	.67
190,	.34	90,	.71
185,	.34	85,	.75
180,	.35	80,	.79
175,	.36	75,	.85
170,	.38	70,	.91
165,	.39	65,	.98
160,	.40	60,	1.06
155,	.41	55,	1.16
150,	.43	50,	1.28
145,	.44	45,	1.42
140,	.46	40,	1.59
135,	.47	35,	1.82
130,	.49	30,	2.13[1]
125,	.51	25,	2.55[1]
120,	.53	20,	3.19[1]
115,	.55	15,	4.25[2]
110,	.58	10,	6.38[2]
105,	.61	5,	12.75[2]

[1] Take 2 grams.

[2] Take 2 grams and use 25 cubic centimeters of Wijs solution.

Supplementary Notes. — Unsaturated acids and their glycerides assimilate halogens with the formation of saturated compounds, and this property serves as a basis for their quantitative determination. Theoretically, chlorine, bromine, iodine, iodobromide or iodochloride may be employed for the purpose. The use of chlorine, however, is impractical, and bromine tends to form both substitution and addition products. Iodobromide (Hanus solution) has no advantage over iodochloride (Wijs solution) except ease of preparation; therefore the latter process, employing the same active agent (iodine monochloride), and agreeing closely with the original Hubl method under control conditions,[1] should be given preference, notwithstanding American practice to the contrary. Furthermore, Wijs has shown[2] that his solution yields practically theoretical results with a number of pure fatty acids. The solution is far more stable than that of Hubl and more rapid in its action.

The structure of unsaturated acids, particularly the position of the double bond in relation to the carboxyl group, influences the iodine absorption.[3] If the double bond is located at a considerable distance from the carboxyl the results are generally normal, but when relatively close together the iodine number is likely to be below theory, although lengthening the absorption period increases the results.

Wijs solution is said to yield high and variable results with cholesterol, and low results with rosin and rosin oils, increasing with the excess of iodine and the length of the absorption periods.

Olein is the principal unsaturated glyceride in nondrying oils and fats, linolin constitutes a considerable proportion of drying and semidrying oils and to some extent of nondrying oils and solid fats, and linolenin occurs in large amounts in all vegetable drying oils. Clupanodonin appears to be the characteristic constituent of fish, liver and blubber oils.

Linolic and linolenic acids and their glycerides absorb oxygen from the air at ordinary temperature and dry to a hard elastic layer, and to this property drying oils owe their value. On drying, such oils[4] absorb oxygen with oxidation of unsaturated acids, resulting in the formation of oxyacids and corresponding loss of iodine number; polymerize with an increase in specific gravity and viscosity and additional loss in iodine number; partially dehydrate with formation of stearolactone; and liberate carbonic acid. These changes result in considerable molecular rearrangement. Oils that have been blown or boiled absorb less iodine. It is stated that for practical purposes drying oils should have an iodine number of at least 140, preferably 170 or higher, and nondrying oils of 90 or under. For purposes of classification Holde limits semidrying oils to a range of 95 to 130. Certain fish oils have a high iodine number and will absorb oxygen, but they do not dry to a hard layer. The fat of marine animals has a higher iodine number than that of terrestrial animals.

Calculated Data from the Iodine Number.

Theoretically, the unsaturated fatty acids belonging to the oleic, chaulmoogric and ricinoleic series absorb 2 atoms of the halogen; linolic and tariric series, 4 atoms; linolenic series, 6 atoms; clupanodonic series, 8 atoms, etc. The members of the chaulmoogric series are cyclic compounds, and contain only 1 pair of double-linked carbon atoms, while open chain acids of the same empirical formula would in most instances contain 2 pairs. Tariric acid contains triple-bond carbon atoms, and although it forms a tetrabromide, it generally absorbs only 1 or possibly 2 halogen atoms. The double-linked carbon atoms may be considered the ethylene type, and the triple-bonded an acetylene linkage. The glycerides act similarly to the free acids and absorb three times as many atoms (triglycerides).

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[1] Lewkowitsch, Analyst, 24, p. 259 (1899).

[2] Chem. Rev. Fett u. Harz Indus., 1899, p. 1.

[3] Lewkowitsch, Analysis of Oils, Fats and Waxes, 1, p. 400 (1913).

[4] Holde-Mueller, Examination of Hydrocarbon Oils, pp. 297–298 (1915).

In those cases where only one such acid or glyceride is present its percentage can be readily calculated from the iodine number by dividing by the theoretical absorption or by means of a factor.

$$\text{Oleic acid} = \frac{2\ \mathrm{I}}{C_{17}H_{33}COOH} = \frac{2\times 126.92}{282.272} = 0.89927$$

$$\text{Olein} = \frac{6\ \mathrm{I}}{(C_{17}H_{33}COO)_3C_3H_5\ \text{[1]}} = \frac{761.52}{884.832} = 0.86064$$

In a similar manner the following figures for theoretical absorption were deduced for the acids and glycerides enumerated below: —

	Acid.			Triglyceride.	
	Molecular Weight of Acid.	Theoretical Iodine Absorption.	Reciprocal.	Theoretical Iodine Absorption.	Reciprocal.
Oleic,	282.272	.89927	1.11201	.86064	1.16193
Erucic,	338.336	.75026	1.33287	.72308	1.38297
Linolic,	280.256	1.81149	.55203	1.73312	.57699
Linolenic,	278.240	2.73692	.36537	2.61770	.38201
Clupanodonic,	276.224	3.67586	.27205	3.51462	.28453
Ricinoleic,	298.272	.85104	1.17503	.81635	1.22496
Sitosterol,	386.368	.65699	1.52209	–	–
Cholesterol,	386.368	.65699	1.52209	–	–

Where there are two unsaturated acids (or glycerides) present (x and y) of known iodine absorption (c and d), if the percentage of the mixture (P) and the iodine number (W) of the fat have been determined, the per cent. of each acid (or glyceride) can be calculated by formula.

$$x + y = P$$

$$cx + dy = .01\ W\ \text{[2]}$$

$$x = \frac{.01\ W - dP}{c - d}$$

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[1] $3(C_{17}H_{33}COOH)+C_3H_2$ or 3m+38.016.

[2] The factor 0.01 converts the iodine number to the same basis as the figures for theoretical absorption stated in the previous table.

ACETYL NUMBER.

The acetyl number indicates the number of milligrams of potassium hydroxide required to combine with the acetyl[1] absorbed by 1 gram of an oil, fat or wax on acetylation.[2]

Reagents. — Acetic anhydride: Kahlbaum's.

Ceresine: pure white, filtered.

Alcohol: redistilled, free from acids and aldehydes.

Alcoholic potash: 50 cubic centimeters of a saturated solution of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of alcohol. The solution should be allowed to stand at least twenty-four hours and filtered immediately before use.

N/2 hydrochloric acid.

Phenolphthalein solution: 1 gram to 100 cubic centimeters of alcohol, neutralized.

Cotton blue 6B solution: 2 grams to 100 cubic centimeters of alcohol. The indicator should be boiled in a flask under a reflux condenser for two hours and then filtered.

Method. — Into a 300 cubic centimeter Erlenmeyer flask are brought 5 grams of fat, together with 10 cubic centimeters of acetic anhydride. The flask is connected with a spiral or other form of reflux condenser and heated in a boiling water bath (immersed in the water) for from one to one and one-half hours. Longer heating yields higher results, but is accompanied by partial decomposition of the fat with formation of aldehydes or other bodies that give a reddish color with caustic alkali. After acetylating, the spiral is removed from the flask and sufficient ceresine added to form a solid disk with the fat when chilled in cold water. The amount of ceresine required will vary with the consistency of the product under examination. For butter fat 0.5 gram is ample; for softer fats and oils, rather more; and for harder fats, less. With the flask still in the water bath, 150 cubic centimeters of boiling water are added with as little disturbance of the fat layer as possible. The flask is then removed and the contents rotated vigorously to dissolve occluded acetic acid. The flask is immersed in cold water to solidify the ceresine fat, after which the solution is decanted through a dense, 12.5 centimeter filter, care being taken not to break the insoluble cake. Another 150 cubic centimeters of boiling water is added, thoroughly agitated, heated a few minutes on the bath, cooled and decanted, the process being repeated until the final filtrate gives a decided color with two or three drops of N/10 alkali, using phenolphthalein as indicator (about six times). Prolonged washing is likely to cause some hydrolysis of the acetylated product.

The filter and inverted flask containing the cake of ceresine fat are allowed to drain in a cool place until practically dry. The small particles adhering to the filter are then scraped into the flask, the inner portion of the filter paper extracted in a small beaker with three successive 20 cubic centimeter portions of boiling alcohol, and poured into the flask; then 50 cubic centimeters of alcoholic potash, accurately measured with a burette, and several glass beads are added. The flask is connected with a spiral or other form of reflux condenser, and the solution boiled on a water bath until saponification is complete, — about sixty minutes. The flask is placed in a water bath at 60° C., and the solution, after cooling to that temperature, titrated with N/2 hydrochloric acid, using 1 cubic centimeter of phenolphthalein or cotton blue as indicator. Cotton blue offers certain advantages in the case of solutions that develop a reddish color with caustic alkali. The alcoholic mixture is again brought to boil to free any alkali occluded in the ceresine, and retitered if necessary. Several blank determinations should be run with every series of tests, under precisely similar conditions as to time and treatment except that the ceresine may be omitted. However, every lot of ceresine must be tested. It should be free from soluble matter and not assimilate any alkali on saponification. The difference between the titration of the blank and that of the excess alkali in the test is the acid equivalent of the fat after acetylation, which should be calculated to milligrams of potassium hydroxide for 1 gram of fat.

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[1] On saponification the acetyl hydrolyzes to acetic acid and combines with the alkali.

[2] Benedikt and Ulzer, and Lewkowitsch report on the basis of the acetylated product.

One cubic centimeter of N/2 acid is equivalent to 28.054 milligrams of potassium hydroxide.

The difference between the saponification number of the fat before and after acetylation is the acetyl number. In case the original fat contains *free soluble* acids their titer should be determined and proper correction made for the same.

Limit of error, 0.50 milligram.

Synopsis of Reaction. — Acetylation of glycerides of monohydroxy and dihydroxy acids, monoglycerides and diglycerides and free alcohols. (See formulas.)

Saponification of the acetylated product. (See formulas.)

Saponification of the original or unacetylated product.

Titration of excess alkali.

Acetyl number by difference.

Glycerides of Monohydroxy and Dihydroxy Acids.

Acetylation.

$$\underset{\substack{\text{triglyceride of}\\ \text{monohydroxy acid}}}{(R\,.\,OH\,.\,COO)_3C_3H_5}+3\underset{\substack{\text{acetic}\\ \text{anhydride}}}{(CH_3CO)_2O}=\underset{\text{acetylated glyceride}}{(R\,.\,OCH_3CO\,.\,COO)_3C_3H_5}+3\underset{\text{acetic acid}}{CH_3COOH}$$

Example: Ricinolein $(C_{17}H_{32}\,.\,OH\,.\,COO)_3C_3H_5$

Saponification.

$$\underset{\text{acetylated glyceride}}{(R\,.\,OCH_3CO\,.\,COO)_3C_3H_5}+\underset{\text{alkali}}{6\,KOH}$$

$$=3\underset{\substack{\text{potassium salt}\\ \text{of hydroxy acid}}}{R\,.\,OH\,.\,COOK}+3\underset{\substack{\text{potassium}\\ \text{acetate}}}{CH_3COOK}+\underset{\text{glycerol}}{C_3H_5(OH)_3}$$

$$\underset{\substack{\text{triglyceride of}\\ \text{dihydroxy acid}}}{[R(OH)_2COO]_3C_3H_5}+(CH_3CO)_2O=\underset{\text{acetylated glyceride}}{[R(OCH_3CO)_2COO]_3C_3H_5}+H_2O$$

Example: Dihydroxystearin $[C_{17}H_{33}(OH)_2COO]_3C_3H_5$

$$[R(OCH_3CO)_2COO]_3C_3H_5+9\,KOH=3\,R(OH)_2COOK+6\,CH_3COOK+C_3H_5(OH)_3$$

Monoglycerides and Diglycerides.

$$\underset{\text{monoglyceride}}{(RCOO)C_3H_5(OH)_2}+(CH_3CO)_2O=\underset{\text{diaceto-glyceride}}{(RCOO)\ (CH_3COO)_2C_3H_5}+H_2O$$

$$(RCOO)\ (CH_3COO)_2C_3H_5+3\,KOH=RCOOK+2\,CH_3COOK+C_3H_5(OH)_3$$

$$\underset{\text{diglyceride}}{(RCOO)_2C_3H_5(OH)}+(CH_3CO)_2O=\underset{\text{monaceto-glyceride}}{(RCOO)_2(CH_3COO)C_3H_5}+CH_3COOH$$

$$(RCOO)_2(CH_3COO)C_3H_5+3\,KOH=2\,RCOOK+CH_3COOK+C_3H_5(OH)_3$$

Free Alcohols.

$$\underset{\substack{\text{monobasic}\\ \text{alcohol}}}{ROH}+(CH_3CO)_2O=\underset{\substack{\text{acetate}\\ \text{of alcohol}}}{CH_3COOR}+CH_3COOH$$

$$CH_3COOR+KOH=ROH+CH_3COOK$$

Examples: Sitosterol, cholesterol, $C_{27}H_{45}OH$

Considerable variation is possible in writing the above formulas which, at best, poorly express the structure. In some instances the reaction is indicated at some sacrifice of form.

Calculated Data from the Acetyl Number.

The acetyl number (c) serves to measure the amount of hydroxy compounds in an oil, fat or wax, and in case only one such compound of known molecular weight (m) and number of hydroxyls (d) is present, its amount (H) can be readily calculated by the following formula: —

$$H=\frac{cm}{56108\,d}$$

The derivation of the formula is comparatively simple. The theoretical acetyl number of a compound containing d hydroxyl groups is: —

$$\frac{56108\,d}{m}$$

The amount of such a compound in an oil, fat or wax is therefore —

$$\frac{c}{\frac{56108\,d}{m}} \text{ or } \frac{cm}{56108\,d}$$

The same results may be calculated more easily from the following table dividing the determined acetyl number by the theoretical acetyl number, or multiplying by its reciprocal: —

Acetyl Number on Original Product.

Glycerides.

NAME.	Formula.	Molecular Weight.	Saponification Number.	Theoretical Acetyl Number.	Reciprocal.
Ricinolein, . .	$(C_{17}H_{32}.OH.COO)_3C_3H_5$	932.832	180.444	180.444	.0055419
Dihydroxystearin, .	$(C_{17}H_{33}(OH)_2COO)_3C_3H_5$	986.880	170.562	341.124	.0029315
Monoglycerides.					
Monopalmitin, . .	$(C_{15}H_{31}COO)C_3H_5(OH)_2$	330.304	169.868	339.736	.0029435
Monostearin, . .	$(C_{17}H_{35}COO)C_3H_5(OH)_2$	358.336	156.579	313.159	.0031933
Monolein, . . .	$(C_{17}H_{33}COO)C_3H_5(OH)_2$	356.320	157.465	314.930	.0031753
Diglycerides.					
Dipalmitin, . .	$(C_{15}H_{31}COO)_2C_3H_5(OH)$	568.544	197.374	98.687	.0101330
Distearin, . . .	$(C_{17}H_{35}COO)_2C_3H_5(OH)$	624.608	179.658	89.829	.0111323
Diolein, . . .	$(C_{17}H_{33}COO)_2C_3H_5(OH)$	620.576	180.826	90.413	.0110604
Hydroxy Acids.					
Ricinoleic, . .	$C_{17}H_{32}.OH.COOH$	298.272	188.110	188.110	.0053160
Dihydroxystearic, .	$C_{17}H_{33}(OH)_2COOH$	316.288	177.395	354.791	.0028186
Free Alcohols.					
Sitosterol, . . .	$C_{27}H_{45}OH$	386.368	–	145.219	.0068862
Cholesterol, . .	$C_{27}H_{45}OH$	386.368	–	145.219	.0068862

Gravimetric Process.[1] — After acetylating, a gravimetric process for acetyl number may be conducted in a manner similar to that for the quantitative determination of insoluble fatty acids, observing all the precautions therein noted as to ceresine, washing, drying, weighing, etc.

This modification is apparently rather more difficult, tedious and subject to error than the saponification or volumetric process. An inaccuracy, due to a deficiency in weight arising from the dehydration of free fatty acids by acetic anhydride during acetylation, is probably unavoidable, although of little consequence where the amount of free acids is relatively small.

The acetyl number (a) is calculated from the increase in weight (i) by the following formula: —

$$a = \frac{56108\ i}{42.016} \quad \text{or} \quad 1335.39604\ i$$

In case only one hydroxy compound of known molecular weight (m) and number of hydroxyls (d) is present, its amount can be calculated from the increase in weight (i) of the oil, fat or wax on acetylating. The theoretical increase for a hydroxy compound is —

$$\frac{42.016\ d}{m}$$

The amount (H) of such a compound in an oil, fat or wax is, therefore —

$$H = \frac{i}{\frac{42.016\ d}{m}} \quad \text{or} \quad \frac{im}{42.016\ d}$$

Molecular Weight of Hydroxy Compounds. — The molecular weight of the hydroxy compounds can be calculated from the weight (w) of fat taken and the increase (i) on acetylating, provided the number (d) of hydroxyls in the molecule is known: —

$$w : w+i :: m : m+42.016\ d$$

$$m = \frac{42.016\ dw}{i}$$

The formation of anhydrides during the acetylating process will affect the accuracy of these calculations.

The computation of the amount of hydroxy compounds by the gravimetric process is greatly facilitated by use of the following table: —

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[1] Has not received sufficient study in this laboratory to warrant positive statements, but is similar to the methods described by Lewkowitsch (*loc. cit.*) 1, pp. 451–453, 578–580 (1913).

Acetyl Gravimetric Process on Original Product.

Glycerides.

NAME.	Molecular Weight.	Molecular Weight after acetylating.	Theoretical Increase in Weight per Gram on acetylating.[1]	Reciprocal.
Ricinolein,	932.832	1058.880	.135124	7.40061
Dihydroxystearin,	986.880	1238.976	.255447	3.91471
Monoglycerides.				
Monopalmitin,	330.304	414.336	.254408	3.93069
Monostearin,	358.336	442.368	.234506	4.26428
Monolein,	356.320	440.352	.235833	4.24029
Diglycerides.				
Dipalmitin,	568.544	610.560	.073901	13.53162
Distearin,	624.608	666.624	.067268	14.86591
Diolein,	620.576	662.592	.067705	14.76996
Hydroxy Acids.				
Ricinoleic,	298.272	340.288	.140865	7.09900
Dihydroxystearic,	316.288	400.320	.265682	3.76390
Free Alcohols.				
Sitosterol,	386.368	428.384	.108746	9.19574
Cholesterol,	386.368	428.384	.108746	9.19574

[1] Acetyl number = 1335.39604 i.

Supplementary Notes. — The various hydroxy compounds that occur in oils, fats and waxes form derivatives on heating with acetic anhydride, the acetyl radical displacing the hydrogen of the alcoholic hydroxyl groups. This property serves as the basis of analytical methods for the quantitative determination of monohydroxy and dihydroxy acids and their glycerides, monoglycerides and diglycerides, and free alcohols.

Glycerides of hydroxy acids are a natural constituent of certain oils and fats, although they do not appear to be very widely distributed in any considerable amount. Castor oil, composed largely of ricinolein, is an excellent illustration. Hydroxy acids probably occur more frequently as the result of oxidation of unsaturated acids. Oleic acid has been shown repeatedly to be comparatively unstable. By the assimilation of oxygen and water it may be converted into dihydroxystearic acid, a saturated compound.

$$C_{17}H_{33}COOH + H_2O + O = C_{17}H_{33}(OH)_2COOH$$

Whether the oxidation takes place in the glycerides or in the fatty acids after hydrolysis is uncertain, although the latter appears the more probable supposition.

Monoglycerides and diglycerides result from the hydrolysis of triglycerides, and free fatty acids condition their presence; the absence of free fatty acids in a commercial product, however, does not necessarily preclude the presence of monoglycerides and diglycerides.

Solid alcohols of the cyclic series (sterols) occur in oils and fats both in combination as esters and as free alcohols.[1] The amount of sitosterol or cholesterol is generally small, often inappreciable, and is indicated approximately by the unsaponifiable matter which it characterizes. Alcohols of the ethane and other series, free and in combination, compose a considerable proportion of waxes.

Oils and fats, therefore, may contain glycerides of monohydroxy and dihydroxy acids, possibly free hydroxy acids, monoglycerides and diglycerides and free alcohols; and the insoluble acids, separated from the oils and fats, may contain monohydroxy and dihydroxy acids and free alcohols. A portion, at least, of the free alcohols found in the insoluble acids probably occurred in the fat as esters. With the exclusion of the natural glycerides of hydroxy acids and a small amount of free alcohols the acetyl number of many oils and fats may be deemed an index of quality, and when considered in conjunction with the acid and iodine numbers may serve to measure (more or less imperfectly, to be sure) the amount of hydrolysis and of oxidation the product has undergone. To differentiate between products of hydrolysis and of oxidation the percentage of insoluble acids and their acetyl number should also be determined.

Of the oils, fats and waxes with an appreciable content of hydroxy compounds[2] might be mentioned candle nut oil, safflower oil, rape oil, peanut oil, olive oil, elderberry oil, Japanese sardine oil, skate liver oil, shark liver oil, seal oil, horses' foot oil, palm oil, bone fat and beeswax, having acetyl numbers between 10 and 20; neat's-foot oil, Japan wax, carnauba wax and wool wax, having acetyl numbers ranging from 25 to nearly 60; and castor oil, having an acetyl number of about 170.

UNSAPONIFIABLE MATTER.

The unsaponifiable matter indicates the percentage of all those components of an oil, fat or wax which on boiling with potassium hydroxide do not form water-soluble compounds.

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[1] See numerous references: Abderhalden, Physiol. Chem. (1908); Hammarsten, Physiol. Chem. (1911); Leathes, The Fats (1910).

[2] Lewkowitsch, Analysis of Oils, Fats and Waxes, 1., pp. 434–435 (1913).

Reagents. — Alcohol: redistilled, free from acids and aldehydes.

Alcoholic potash solution: 50 cubic centimeters of a saturated solution of potassium hydroxide, free from carbonate, to 1,000 cubic centimeters of alcohol. The alkali should be added to the alcohol slowly, with agitation, in order to prevent any appreciable rise in temperature.

Methyl alcohol: redistilled, free from acids and aldehydes. The alcohol is prepared from Columbian spirits by distillation over caustic lime.

Potassium carbonate: anhydrous, free from caustic alkali.

Ethyl ether:[1] anhydrous, free from alcohol and residue. The ether should be allowed to stand over metallic sodium until evolution of gas ceases, and then redistilled.

Method.[2] — Five grams of fat are brought into a 300 cubic centimeter Erlenmeyer flask, together with 75 cubic centimeters of alcoholic potash and 25 cubic centimeters of alcohol. The flask is connected with a spiral or other form of reflux condenser and the solution boiled on a water bath with occasional rotating of the contents until saponification is complete, — about sixty minutes. The solution is transferred to a 250 cubic centimeter Griffin beaker and the flask rinsed several times with hot alcohol. The alcohol is evaporated in a water bath (with the beaker immersed in the water) at a gradually increasing temperature. Several 25 cubic centimeter portions of methyl alcohol are added and evaporated to insure *complete dryness.* Careful heating is necessary to avoid spattering.

The dry residue is pulverized in a mortar with 25 grams of anhydrous potassium carbonate, dried two hours at 100° C., transferred to an S. & S. extraction thimble, 33 by 80 millimeters, extracted two to three hours with anhydrous ether in a continuous extracter (see Fig. 4), and the ether expelled as usual. Notwithstanding the precautions mentioned, moisture may be absorbed during the process and vitiate the ether extract with a small amount of water-soluble compounds. To eliminate this error the air-dry extract is washed with several 25 cubic centimeter portions of water at room temperature, and decanted on an ether-extracted filter which is air dried, and extracted with ether, using the same flask as before. The purified extract is dried from 1 to 1.5 hours in an oven at 100° C. and considered unsaponifiable matter.

In most oils and fats there is a comparatively small amount of unsaponifiable matter, but greater accuracy is not insured by taking a larger amount of material (say 10 grams), for the reason that the greater the bulk of soap the more difficult the manipulation.

Seventy-five cubic centimeters of alcoholic potash instead of 50 cubic centimeters, the usual quantity, are employed to prevent any reversible reaction to which there appears to be a tendency on evaporating. One hundred cubic centimeters, however, destroy a portion of the sterols.

Anhydrous potassium carbonate proved a more efficient dehydrating agent than the corresponding sodium salt.

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[1] Commercial ether of the U. S. P. grade is unfit for the purpose, and the "distilled over sodium" grade is often unreliable, due to its hygroscopic properties.

[2] Not applicable for volatile hydrocarbons or ethereal oils.

Limit of error, 0.05 per cent.

Synopsis of Reaction. — Saponification of the fat with alcoholic potash.

Evaporation of the alcohol and dehydration of the soap.

Extraction of the unsaponifiable matter with ethyl ether.

Purification of the extract.

Supplementary Notes. — In terms of the definition, the components of unsaponifiable matter do not form water-soluble compounds on boiling with potassium hydroxide. They are largely soluble, however, in the soap solution, which is a factor to be noted in their separation by ethyl ether from water or dilute alcoholic solutions. Furthermore, water hydrolyzes neutral soaps, and alcoholic solutions containing less than 50 per cent. alcohol are unreliable for the same reason, as described under "Acid Number." Soaps are soluble in moist ether. The extraction of un-

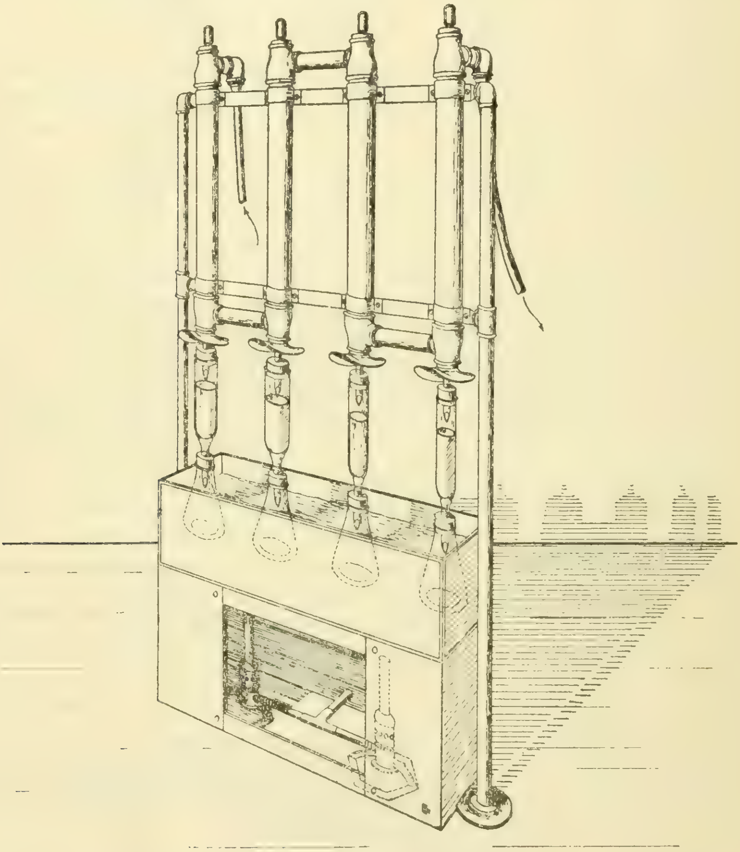

FIG. 4. — Ether extraction apparatus employed in the determination of unsaponifiable matter.

saponifiable matter in the dry state, therefore, promises more trustworthy results, although it is a more lengthy process and not entirely free from criticism.

The unsaponifiable matter of oils and fats consists principally of the solid alcohols of the cyclic or aromatic series, the so-called sterols (sitosterol, stigmasterol, brassicasterol and cholesterol). In some products occur alcohols of the ethane series (ceryl and melissyl) and hydrocarbons, also small amounts of coloring matter, resinous substances, ethereal oils, nitrogenous bodies (lecithin, mucilaginous matter), etc.

Sitosterol is the characteristic concomitant of vegetable oils and fats, and cholesterol of animal. The former alcohol is sometimes accompanied by stigmasterol or brassicasterol. Stigmasterol has been found in soy bean oil, calabar bean oil and rape oil.

Ceryl and melissyl alcohols are the only members of the ethane series that appear to have been identified.

Hydrocarbons have been reported in buckthorn oil, kosam seed oil, parsley seed oil, cantharides oil, chrysalis oil, laurel oil and cacao butter. The unsaponifiable matter of laurel oil has a high iodine number. The chromogenic bodies give the color reactions in identification tests of cottonseed, sesame, liver oils, etc. Ethereal oils occur in nutmeg butter.

Remnants of vegetable or animal tissue are purely adventitious substances, and should always be excluded.

Among extraneous substances that may appear in the unsaponifiable matter are mineral oils (petrolatum and shale oils), tar oils (neutral coal oils), paraffin, ceresine, rosin oils, etc. They occur in the oils and fats as adulterants.

The amount of unsaponifiable matter in oils and fats varies from a trace to several per cent. Corn, cottonseed and sesame oils show over 1 per cent. in some instances, while rape, peanut and olive oils appear to average less. Fish, liver and blubber oils, such as herring, cramp fish, cod liver, shark liver, whale and porpoise oils, sometimes contain 10 or even 20 per cent. Old rancid fats yield larger amounts than fresh fats.

The unsaponifiable matter of waxes includes alcohols of the ethane series (cetyl, ceryl, melissyl, etc.), of the cyclic series (sitosterol, cholesterol and isocholesterol) and of several other series seemingly less prominent, and of hydrocarbons. The alcohols in the natural product evidently occur both free and in combination with fatty acids as esters. They are mostly monatomic, the more common belonging to the ethane series.

Sitosterol is found in vegetable flax wax, and cholesterol and isocholesterol in wool wax and probably in beeswax.

Hydrocarbons constitute an appreciable amount in waxes, particularly in the case of the solid waxes.

Adulterants similar to those of oils and fats may be expected.

The unsaponifiable matter in liquid waxes varies from 31 to 43 per cent., and in solid waxes from 43 to 55 per cent.

Sterols.

The sterols indicate the percentage of cyclic alcohols in an oil, fat or wax.

Reagents. — Ninety-five per cent. alcohol:[1] redistilled, free from acids and aldehydes.

Digitonin solution: 1 gram to 100 cubic centimeters of 90 per cent. alcohol.

Ethyl ether.

Windaus Method.[2] — The unsaponifiable matter is dissolved in boiling 95 per cent. alcohol in the proportion of 1 to 50, and the sterols precipitated with an excess of hot digitonin solution. After standing overnight at room temperature, the precipitate is brought into a tared Gooch crucible with 95 per cent. alcohol, washed with alcohol and then with ether, dried in an oven at 100° C., and weighed as digitonin-sterol. Digitonin unites with the sterols, molecule for molecule, to form an addition product without loss.

From the weight obtained the percentage of sterols can be calculated by the factor 0.2431.

Limit of error, 0.05 per cent.

Synopsis of Reaction. — Solution of the unsaponifiable matter in hot alcohol.

Precipitation of the sterols with digitonin.

$$C_{27}H_{45}OH + C_{55}H_{94}O_{28} = C_{82}H_{140}O_{29}$$

Filtration and weight of digitonin-sterol.

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[1] See "Reagents" under "Saponification Number."

[2] Ztschr. Phys. Chem., 65, pp. 110–117 (1910).

BULLETIN No. 167 JANUARY, 1916

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

I

THE RELATION OF HYDROGEN ION CONCENTRATION OF MEDIA TO THE PROTEOLYTIC ACTIVITY OF BACILLUS SUBTILIS

II

PROTEOLYSIS OF STREPT. ERYSIPELATIS AND STREPT. LACTICUS COMPARED UNDER DIFFERENT HYDROGEN ION CONCENTRATION

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Department of Microbiology, Massachusetts Agricultural College

This publication involves two parts, as follows:

Part I. — This investigation has been undertaken to determine the bacteriological value of Sörensen's method for the study of proteolysis in conjunction with hydrogen ion concentration. In its execution it has been thought wise to select the well-known organism, B. subtilis, which enables ready interpretation. The investigation shows that certain hydrogen ion concentrations measure the exact influence both inhibitory and prohibitory, and indicate the exact limits of the proteolytic activity of B. subtilis. It shows, further, that the hydrogen ion concentrations of the medium converged toward the optimum as proteolysis proceeded. From this point it will be carried into specific fields of application in agriculture.

Part II. — The method established in Part I. has been employed to differentiate the proteolytic activity of Streptococcus erysipelatis and Streptococcus lacticus, organisms of peculiar and mooted significance in milk. It should be understood, however, that this is only a preliminary statement, and an exhaustive study is a matter of the future.

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[1] On account of ill health not in administrative charge.

[2] In administrative charge.

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NOTE. — This publication represents a thesis to be offered for the degree of doctor of philosophy.

APPROVED BY THE STATE BOARD OF PUBLICATION.

DEPARTMENT OF MICROBIOLOGY.

PART I.

THE RELATION OF HYDROGEN ION CONCENTRATION OF MEDIA TO THE PROTEOLYTIC ACTIVITY OF BACILLUS SUBTILIS.

BY ARAO ITANO.

INTRODUCTION.

Since the physico-chemical methods were introduced into the field of biology, the influence of ions, such as Na, Ca, Cl, H, upon the vital processes has been increasingly recognized by biologists. This influence is manifested in many phases of biology. In this investigation the relation of the hydrogen and hydroxyl ion concentration, or "true acidity" and "true alkalinity"[1] of media, to the proteolytic activity of *B. subtilis* has been studied.

The importance of the effect of hydrogen ion concentration of media upon the bacterial growth has been well known to bacteriologists, but it has been impossible to determine the so-called "true reaction." With the introduction of physico-chemical methods, progress toward the measurement of absolute reaction has been made.

So far as the author knows, Brünn,[2] in 1913, was the first to undertake the investigation of the disinfecting property of acids upon *B. coli* and *B. typhosus.* He found that the hydrogen ion concentrations 2×10^{-5} and 1×10^{-5} at 37° C. for twenty-four hours have a corresponding germicidal effect. Since then, several other investigators have performed similar experiments with the hydrogen ion concentration, employing several species of bacteria for their test. The author fails, however, to find that any investigation in the light of hydrogen ion concentration has been conducted on the subject of proteolysis instigated by bacteria. Brünn's experiment illustrates the influence of hydrogen ion concentration upon bacterial life. In other biologic fields, however, considerable work has been done to point out the importance of such an experiment on the several physiologic processes. Sörensen[1] studied extensively the influence of different hydrogen ion concentrations upon enzymes, and concluded that enzymatic action can be controlled by adjusting the reaction of media. In the medical world the phenomena of "acid intoxication" in different forms have suggested the importance of the study of "true acidity" of blood and urine. Michaelis[2] pointed out the clinical importance of the "true reaction" of the blood. Henderson and Palmer[3] have demonstrated the clinical value of "true reaction" in its relation to the urine. Their results are not specific unless they are to indicate the normal and abnormal condition of the body.

---

[1] "True acidity" and "true alkalinity" are the common terms adopted by S. P. L. Sörensen to express the H and OH ion concentration.

[2] Über das Desinfektionsvermögen der Säuren. Diss., Berlin, 1913.

In agriculture, several perplexing problems have presented themselves in which the hydrogen ion concentration is involved. Such subjects as the acidity of soil, of plants, of milk and of many other substances in both the organic and inorganic world are now the problems of agricultural investigations. Since this acidity is caused only by the dissociated hydrogen ions, regardless of the exact nature of the chemical compound, a better understanding of the "true reaction" is evidently desirable.

The importance of proteolysis in decomposition of proteins is so well understood that further consideration is unnecessary, except a mention of its association with dairy, food and soil studies. So much weight is attached to it that it has become fairly basic to all scientific advancement. In order to make the study yield easily to confirmation, *B. subtilis* has been selected because of its well-known characteristics for identity. This organism makes a good starting point from which the proteolysis of other organisms may be investigated and paralleled.

While we recognize that hydrogen ion concentration is only one factor in proteolysis, the significance attached to it must lend considerable force to its solution. The progress has been extremely slow awaiting the development of the chemistry of proteins. The author is familiar only with Sörensen's formol titration method[4] as the one serving to secure the additional knowledge of proteolysis. So far as it has been applicable it seems very satisfactory.

Classification in microbiology seems at present to be based upon the morphology and biometric characters. There is a subcurrent of feeling that physiologic properties are so variable that they are not reliable. This may not hold true, however, if it becomes possible to use more exact physiologic methods, for through them may be found those delicate differences which are more or less constant and recognized in the metabolism of higher organisms. Then, too, if morphology is a mere expression of physiology and the molecular mechanism of organisms, there is greater reason for looking more deeply into the relation of hydrogen ion concentration as manifested in different species and varieties.

---

[1] Ergebnisse d. Physiologie, 12, 449 (1912).

[2] Die Wasserstoffionenkonzentration, 85, 1914.

[3] Jour. of Biol. Chem., V. 13, No. 4, Jan., 1913.

[4] E. Abderhalden. Handb. d. Biochem. Arbeitmethoden, Bd. 6, S. 262, 1912; Comptes rendus du Laboratoire de Carlsberg, 7, 1, 1907; Biochem. Zeitschr., 7, 43, 1907.

REVIEW OF PREVIOUS INVESTIGATIONS.

The influence of acidity and alkalinity upon biologic processes has been investigated by many who are engaged in the study of general physiology, as has been intimated in the introduction. In physiologic investigation of bacterial life, Kisch's method[1] was generally employed previous to the introduction of the physico-chemical method. Sieber[2] investigated the antiseptic value (minimum dose) of different acids upon various bacteria. Schlüter[3] found that *M. prodigiosus* grows very well in lactic acid 0.1 per cent., but not higher. Carbett[4] showed that *Bacterium diphtheriæ* is able to grow in higher acidity than *M. prodigiosus*. Proskauer and Beck[5] pointed out that *Bacterium tuberculosis* lives in higher acidity than the other organisms mentioned above.

Similar experiments were carried out to determine the influence of alkalinity. Kitasato[6] demonstrated that *B. typhosus* is killed by 0.1 to 0.14 per cent. KOH and *Vibrio choleræ* by 0.18 per cent. KOH solution. Liborius[7] experimented with potassium carbonate and discovered that most bacteria withstood 0.5 per cent., *B. typhosus* 0.8 per cent. and *Vibrio choleræ asiaticæ* 1.0 per cent. K_2CO_3 solution. Deeleman[8] ascertained that the optimum alkalinity for most bacteria is approximately between 0.34 and 1.7 per cent. normal NaOH.

Again literature cites many instances to show the influence of acidity and alkalinity upon the bacterial proteolytic enzyme. Wood,[9] studying proteolytic enzymes from different bacteria, found that these enzymes varied greatly in their power of resisting acid media, and noticed also that the bacteria themselves showed a varying susceptibility to acid, corresponding exactly to their enzymes. Fermi[10] recognized that the enzymes of several bacteria, *M. prodigiosus, B. pyocyaneus, Bact. anthracis* and others, work most advantageously in faintly alkaline solution, although they attack a solution of gelatin containing 0.5 per cent. HCl.

Besides these purely physiologic experiments, numerous references may be found in literature which deal with the reaction of culture media upon the morphology and general physiology of bacteria. Fuller[11] reviewed quite completely the literature of this subject which is treated in his publication. There is indicated a marked influence of media-reaction upon pigment formation, and even upon the morphology, etc., of different bacteria. According to Fuller's publication, moreover, all these investigations were based on the reaction of media which were adjusted by either Schültz's[1] or Fuller's[2] scale, or the so-called "scale of reaction" which will be discussed later. Considering these investigations in the light of the physico-chemical methods of the present day, the influence of the so-called "true acidity" or "true alkalinity" on bacterial life is not sufficiently known, because Kisch's method, as well as others which will be presented in detail later, is not applicable.

---

[1] Kisch, B. Biochem. Zeitschr., 40, 152, 1912.
[2] Jour. Prakt. Chem., 19, 433, 1879.
[3] Zeitschr. Bakt., 11, 589, 1892.
[4] Ann. Inst. Pasteur, 11, 251, 1897.
[5] Zeitschr. Hyg., 18, 128, 1894.
[6] Zeitschr. Hyg., 3, 418, 1888.
[7] Ebenda, 2, 1896.
[8] Arb. kais. Gesundh. Amt., 13, III, 1897.
[9] Laboratory Reports, Roy. College Phys., Edinburgh, V, II.
[10] Centralbl. f. Bakt., Bd. 16, 176, 1906.
[11] Jour. Amer. Pub. Health Assn., 1895, 20, 381.

Recently, with the development of a physico-chemical method, it has become possible to measure the hydrogen ion concentration and also to apply it in the field of biologic investigation. Of late, as already related, several biochemists and biologists have employed the method in various lines of work, such as hydrogen ion concentration in blood, urine, wine, milk, water, etc.[3] As yet, references on the direct bacteriological work are comparatively rare. Beside Brünn's investigation,[4] which was mentioned in the introduction, Michaelis and Marcola[5] investigated the acid production by *B. coli*, and found that it produces lactic acid in alkaline lactose nutrient broth until it reaches a hydrogen ion concentration designated as $P_H = 5$, when the action ceases. Clark's recent investigations[6] concerning the reaction of bacteriologic culture media, by both old (titrimetric) and new (hydrogen electrode) methods, will be discussed later, together with the physiologic importance of hydrogen ion concentration. Clark pointed out the fallacies of the titrimetric method, and noted the advisability of substituting a colorimetric method. He experimented also with several different enzymes, such as trypsin, maltase, urease and others, and marked the approximate range of hydrogen ion concentration and degree of their activity. Clark and Lub[7] employed the hydrogen electrode to determine the change in hydrogen ion concentrations in various cultures of the colon-ærogenes family, and established the correlation between the gas ratio and hydrogen ion concentration in the culture medium. They recommend the use of indicators, *i.e.*, paranitrophenol or methyl red, for differentiation of bacteria of this family.

These investigations added some knowledge regarding the influence of hydrogen ion concentration upon the bacterial life. This investigation deals more comprehensively with the influence of hydrogen ion concentration on bacterial life, together with other matters.

The proteolytic activity of bacteria has attracted much attention from bacteriologists. Many observations and experiments have been carried out since gelatin has been used as a culture medium. In 1886 Bitter[8] discovered that microörganisms subjected to a temperature higher than thermal death point retain the ability to liquefy gelatin, although the microörganisms themselves are killed. Hankin[1] showed that an extract made from *Bact. anthracis* contains an enzyme which is capable of forming albumoses from fibrin. Sirotinin[1] has proved that certain bacteria produce exo-enzymes. Brunton and MacFadyen[2] found that the secretion of certain enzymes by a particular bacterium is influenced by the constituents of the media in which it is cultivated, and also that its activity is governed by the acids and alkalis present. Wood[1] extracted enzymes from the culture media in which several known bacteria were cultivated. Thus far these workers have dealt with the proteolytic activity of bacteria qualitatively, and have noted some of the operating influences. It was Fermi who attempted to determine quantitatively the proteolysis caused by different bacteria. He measured the amount and rapidity of gelatin solution. Besides gelatin, Fermi[3] experimented with other protein substances, such as fibrin, egg albumin, coagulated serum-albumin, using the enzymes secreted by various bacteria; but he found that the greatest activity in proteolysis is secured in gelatin. His investigation is not tenable because room temperatures fluctuate widely and cannot furnish exact conditions of growth. The influence of the liquefying of gelatin by heat upon proteolysis must make the results variable. There is an optimum temperature for proteolysis as well as for the growth of microörganisms; consequently, only definite temperatures can be used for its study. Eijkmann[4] employed milk agar in the study of different microorganisms. The results obtained, however, were only approximate. Later, Abderhalden and Koelker[5] and others introduced the polariscope to determine the degree of proteolysis; but this method is not well adapted to general work on account of turbidity of growth and the slight degree of polarization. With the development of protein chemistry it became possible to ascertain quantitatively the cleavage products. Rosenthal and Patai[6] investigated the proteolytic activity of streptococci, staphylococci and the colon group by the formol titration method of Sörensen, which is yet to be discussed.

---

[1] Centralbl. f. Bakt., O, 1891, 10, 52.

[2] Jour. Amer. Pub. Health Assn., 1895, 20, 381.

[3] Michaelis, L. Die Wasserstoffionenkonzentration, 84, 1914, Berlin.

[4] Uber das Desinfectionsvermögen der Säuren. Diss., Berlin, 1913.

[5] Zeitschr. f. Immunitätsforschung, 1912, 14, 170.

[6] Jour. of Infect. Diseases, V. 17, No. 1, July, 1915, 160–173.

[7] Jour. of Infect. Diseases, V. 17, No. 1, July, 1915, 109–136.

[8] Archiv. f. Hygiene, Bd. 5, 1886.

QUESTIONS INVOLVED.

The problems involved in the proposed investigation are presented diagrammatically.

A brief explanation follows: —

The object of this investigation is to study the influence of hydrogen ion concentration of media upon the proteolytic activity of *B. subtilis*.

After reviewing the previous literature it was necessary to consider the following details of procedure: —

---

[1] Green, R. Fermentation. Cambridge Nat. Science Manual, 1899.

[2] Proc. Roy. Soc., 46, 1889, 542.

[3] Archiv. f. Hygiene, V. 10, 1, 1890; V. 14, 1, 1892.

[4] Centralbl. f. Bakt., Abt. I, Bd. 29, U. 35.

[5] Zeitschr. f. Physiol. Chem., Bd. 51, 294, 1907.

[6] Centralbl. f. Bakt. (Originale), Bd. 73, Heft 6, April, 1914, S. 406–412.

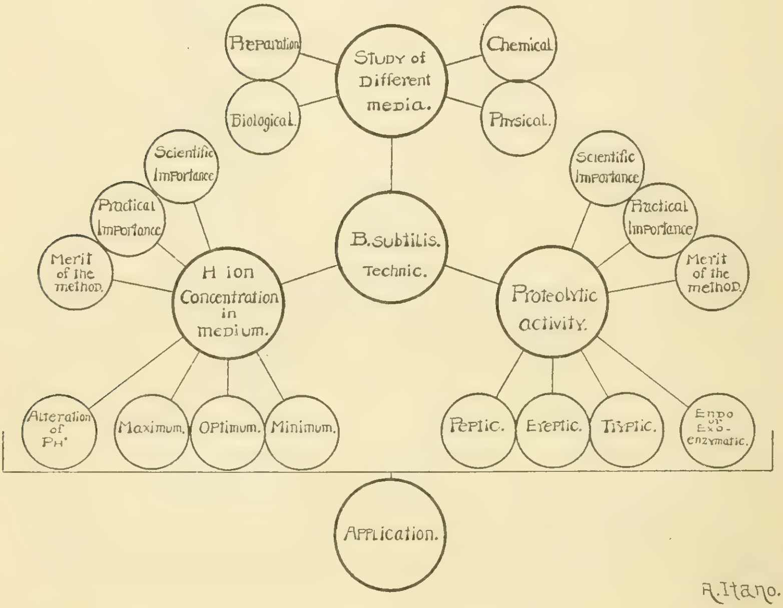
1. Choice of methods to measure —

(*a*) the hydrogen ion concentration in the culture medium.

(*b*) the proteolytic activity quantitatively.

2. Choice of a proper medium, *i.e.*, one which gives uniform results biologically, chemically and physically.

Diagrammatical Representation of the Problems Involved in the Present Investigation.



3. Preparation of media of different hydrogen ion concentrations so that minimum, optimum and maximum hydrogen ion concentration may be determined.

4. Acclimatization to secure organism of constant habit.

5. Inoculation of medium for uniformity of growth.

6. Test for vitality of the organism in media of different hydrogen ion concentration.

7. Determination of the rate of growth.

8. Determination, from time to time, of hydrogen ion concentration.

9. Determination of the rate of proteolysis.

10. Determination of the kind of proteolysis, viz., peptic, ereptic, tryptic-like.

11. Determination of the character of the enzyme, namely, endo- or exo-enzyme.

GENERAL METHODS OF PROCEDURE.

Choice of Methods.

Determination of the Hydrogen Ion Concentration in Culture Media.

A theoretical discussion of "true reaction" will be pertinent at this stage.

"True Reaction" (*"True Acidity," "True Alkalinity," "True Neutrality"*).[1] — The "true acidity" of an acid solution is brought about by the dissociated (hydrogen) ions; therefore the acidity is proportional to the concentration of the dissociated hydrogen ions, and not to the total gram molecules of acid present. For example, if one-tenth normal hydrochloric acid is taken, approximately only 91 per cent. of the total amount of acid becomes dissociated. The " true acidity," *i.e.*, the hydrogen ion concentration, of this solution is only 91 per cent. of the one-tenth normal hydrochloric acid, or ninety-one thousandths normal. The dissociation of weak acid is still less. For instance, in a solution of one-tenth normal acetic acid only $1\frac{3}{10}$ per cent. approximately of the total acid is dissociated, and the hydrogen ion concentration of this solution is therefore thirteen ten-thousandths normal. The " true acidity " of one-tenth normal hydrochloric acid is also about seventy times greater than that of one-tenth normal acetic acid, although both solutions contain the same amount of acid.

The same holds true with the electrically dissociated base in which the metallic and hydroxyl ions are dissociated. The "true alkalinity" of such a solution is not determined by the total amount of base present, but exclusively by the concentration of dissociated hydroxyl ions. For example, in a one-tenth normal solution of the strong base, sodium hydroxide, about 84 per cent. of the total amount of the base is dissociated, and in the case of a weak base, such as ammonium hydroxide, approximately $1\frac{4}{10}$ per cent. of the total amount of the base. The " true alkalinity " of these solutions, therefore, is eighty-four thousandths normal and fourteen thousandths normal, respectively. Thus, regarding the alkalinity as in the case of acidity, we may say in conclusion that " true alkalinity " of a solution is proportional to the concentration of hydroxyl ions.

From the above discussion, "true neutrality" of a solution may be stated as follows: it is a solution in which the same amount of H and OH ions are present. For example, a "true neutral solution," viz., pure water, contains as many hydrogen ions as hydroxyl ions. It can be expressed as follows: —

$$H_2O \rightleftharpoons \overset{+}{H} + \overset{-}{OH}$$

in which $C_{\overset{+}{H}} = C_{\overset{-}{OH}}$, C indicating the concentration.

Again, a solution may not necessarily be neutral, although it contains equivalent quantities of acid and alkali. For example, if a solution which contains hydrochloric acid and sodium hydroxide is taken, it can be expressed in the following manner: —

---

[1] Sörensen, S. P. L. Ergebnisse d. Physiologie, 12, 399, 1912.

$$\underset{\text{hydrochloric}}{\underline{\overset{+}{\mathrm{H}}\quad\overset{-}{\mathrm{Cl}}}} + \underset{\text{sodium hydroxide}}{\underline{\overset{+}{\mathrm{Na}}\qquad\overset{-}{\mathrm{OH}}}} = \underset{\text{salt}}{\underline{\overset{+}{\mathrm{Na}}\ \overset{-}{\mathrm{Cl}}}} + \underset{\text{water}}{\underline{\mathrm{HOH}}}$$

This solution is neutral only when it contains just as many hydrogen as hydroxyl ions, or when both the acid and alkali are equally dissociated.

It is understood, therefore, that the "true acidity, alkalinity and neutrality" are not determined by the amount of such substances present, but entirely by the H and OH ion concentration.

With the above facts in mind it becomes possible to enter upon a more intelligent discussion of the methods involved. It has been stated previously that most bacteriologic experiments, having for their purpose the study of reaction upon bacterial life, fall under the following procedures: —

(*a*) Kisch's method.[1]

(*b*) Ordinary titration method.

(*c*) Colorimetric method.

It is well known that Kisch's method is a dilution method wherein a certain number of gram molecules of an acid or alkali are diluted to a definite quantity for the purpose of ascertaining the influence of the reaction upon the life of bacteria. There are two distinct ways to apply Kisch's method, namely: (*a*) immersing the bacteria in different dilutions of acids or alkalis in pure water for different periods of time by means of silk threads or any other convenient agents, and then testing their vitality; or (*b*) adding a known percentage of acids or alkalis directly to the culture medium (usually solution). In either case the results obtained by Kisch's method indicate neither the influence of "true reaction" upon bacterial life nor the influence of molecular concentration, because, as Lingelheim[2] has shown, different acids of the same molecular concentration have varying influence upon bacteria, and the degree of influence is parallel to the dissociation constant of an acid or alkali. This is especially true in the case of the second manner of application, (*b*), where adsorption is caused by the culture medium.

The ordinary titration method is generally employed in adjusting reaction of culture medium, and also to measure the amount of acid or alkali produced in the course of physiologic tests. This method is inaccurate in the study of physiologic liquids containing more or less amphoteric substances and a comparatively small quantity of H or OH ions. In other words, it is impossible to determine the "true reaction" in such a liquid by this method. Fuller's[3] and Schültz's[4] methods of adjusting the scale of reaction of culture media are scientifically condemned by the recent investigation of Clark,[1] who showed the fallacies of the titrimetric method. Again, the adsorption phenomenon caused by the amphoteric substance in the course of titration is well known, and, in the case of albumin, is usually expressed in the following manner: —

---

[1] Biochem. Zeitschr., 40, 152, 1912.

[2] Zeitschr. f. Hyg., 8, 201.

[3] Jour. Amer. Pub. Health Assn., 1895, 20, 381.

[4] Centralbl. f. Bakteriol., O, 1891, 10, 52.

$$\text{In acid solution H. albumin. OH} = \text{H } \overset{+}{\text{albumin}} + \overset{-}{\text{OH}}$$

$$\text{In alkali solution H. albumin. OH} = \overset{-}{\text{Albumin}}\text{ OH} + \overset{+}{\text{H}}$$

The correctness of the above statement has been experimentally demonstrated by Sörensen,[2] Clark[3] and others.

In many cases the colorimetric method gives fairly accurate results,[4] but it has been noted that the presence of neutral salts as well as amphoteric substances interfere with the determination.[5] It may, however, be employed successfully if it is standardized for the particular liquid.[6] Lately Clark and Lub[7] employed the principle of the colorimetric method for the differentiation of the colon-ærogenes family, using suitable indicators. They have based their experiment upon the wide divergence of the hydrogen ion concentration in a culture of one group and of the other, and distinguished this difference by means of paranitrophenol or methyl red. The use of this method for physiologic work other than bacteriology has been practiced by many. Sörensen and Palitzsch[8] determined the hydrogen ion concentration of sea water. Henderson and Palmer[9] used it in determining the acidity of urine to diagnose normal and abnormal conditions. In any case, the colorimetric method should be standardized previous to its use, by means of the hydrogen electrode.

Examining these methods critically in the light of physical chemistry they are not satisfactory for the purpose of ascertaining the influence of the so-called " true reaction " upon bacterial life. The hydrogen electrode was devised to determine the hydrogen ion concentration, and it has been used successfully in biologic fields. This method has been employed in the present investigation, and its theoretical and practical discussion follows.

Theory of H Ion Concentration. — The announcement of the theory of electric dissociation by Svante Arrhenius, in 1887, marked a new era in physical chemistry. It was F. Kohlrausch and A. Heydweiller who demonstrated that even the purest water is a conductor of electricity, and accordingly prepared a distilled water of the least specific conductance. They measured the specific conductance by means of electric conductivity.

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[1] Jour. of Infect. Diseases, V. 17, No. 1, July, 1915, 109.

[2] Ergebnisse d. Physiologie, Bd. 12, 423, 1912.

[3] Jour. of Infect. Diseases, V. 17, No. 1, July, 1915, 109–136.

[4] Michaelis, L. Die Wasserstoffionenkonzentration, 176, 1914.

[5] Michaelis, L., and P. Rona. Biochem. Zeitschr., 23, 61, 1909.

[6] Michaelis, L. Die Wasserstoffionenkonzentration, 176, 1914.

[7] Jour. of Infect. Diseases, V. 17, No. 1, July, 1915, 160–173.

[8] Biochem. Zeitschr., 51, 307, 1913.

[9] Jour. of Biol. Chem., V. 13, No. 4, Jan., 1913.

Later, other methods for the estimation of dissociation were established, and the results obtained by Kohlrausch were confirmed. Now it is proved that a very small portion of the water molecule is dissociated into two electrically charged parts (or ions), as follows: —

$$H_2O \rightleftharpoons \overset{+}{H} + \overset{-}{OH}$$

Its dissociation takes place according to the law of mass action in accordance with the following equation: —

$$\frac{(H)(OH)}{(H_2O)} = K \qquad (1)$$

in which K denotes the ionization constant; that is to say, the product of the hydrogen and hydroxyl ion concentration, divided by the concentration of the undissociated water molecule, should be constant.

The concentration of water is generally constant. Therefore it may be expressed as follows: —

$$(H) \,.\, (OH) = Kw \qquad (2)$$

in which Kw denoted $K.H_2O$, or ionization constant of water.

Equation (2) is another form of equation (1).

Note. — (H) and (OH) express the concentration.

This ionization constant of water has been determined by several noted physical chemists, and found to be 10^{-14} at 22° C.; that is,

$$(H) \,.\, (OH) = Kw \quad \text{or}$$
$$Kw = 10^{-14} \qquad (3)$$

Since pure water is a neutral solution it contains the same number of dissociated hydrogen and hydroxyl ions. Therefore equation (3) can be expressed as follows: —

$$10^{-7} \times 10^{-7} = 10^{-14} \qquad (4)$$

That is, a pure water contains of each 10^{-7} dissociated hydrogen and hydroxyl ions, or .0000001 gram ions per litre, which is, in a general term, one ten-millionth normal $\frac{N}{10,000,000}$. The acidity, alkalinity and neutrality, therefore, are expressed in terms of hydrogen ion concentration in the following manner: —

Acid reaction $(H) > 10^{-7}$
Alkaline reaction $(H) < 10^{-7}$
Neutral reaction $(H) = 10^{-7}$

Note. — $(\times)$ = notation of the concentration of ions.

That is, in an acid solution there are more than $\frac{1}{10,000,000}$ gram molecule of dissociated hydrogen; in an alkaline solution, less; and in a neutral solution, just $\frac{1}{10,000,000}$ gram molecule. Thus the reaction is usually expressed in terms of hydrogen ion concentration unless it is indicated otherwise.

From the above discussions it is readily seen that if the ionization constant is known, and the hydrogen ion concentration is determined experimentally, then the hydroxyl ion concentration can be calculated. The determination of hydrogen ion concentration is accomplished by the use of the gas cell, of which the principle is based upon the potential of the chain. This chain, as described in physical chemistry, consists of —

$Hg - HgCl$	n/10 KCl	conc. KCl	solution	$Pt\ H_2$
calomel	electrode	concentr. potassium chloride in a dish.	(unknown)	platinum electrode saturated with hydrogen gas.

The potential of such a chain can be determined by the usual physical method. Then the relation between the measurement of potential and hydrogen ion concentration can be calculated by the following equation: —

$$P_{\dot{H}} = \frac{P - 0.3377}{0.0577 + 0.0002\ (t^\circ - 18^\circ)}$$ [1]

where —

$P_{\dot{H}}$ — the term adopted by S. P. L. Sörensen to express the exponent of gm. — equivalent of hydrogen ions per liter. [2]

P — the total E. M. F. of the chain. It can be determined by the following equation, having the apparatus arranged as it is shown in the diagram: —

$P = \frac{R_1 \times 1.0189}{R}$, in which R_1 — the bridge reading for the chain against an accumulator.

R — the bridge reading for the accumulator against the normal element.

1.0189 — the voltage of the normal element at 18°C. (standard).

0.3377 [3] — the sum of potential of calomel electrode (N/10 KCl) and hydrogen electrode in a solution where the hydrogen concentration is normal $(H) = 1$ or $P_{\dot{H}} = 0$.

0.0577 [4] — thermodynamical factor at 18° C. which is influenced by temperature, 0.0002 for each degree centigrade, or it changes as follows: —

$0.0577 + 0.0002\ (t^\circ - 18^\circ)$, of which t° equals temperature at the time of determination.

After $P_{\dot{H}}$ is determined it is necessary to understand the value of H ion concentration, although the experimental results are generally expressed in $P_{\dot{H}}$. It will be shown at the end of an example, illustrating the application of the formula as well.

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[1] Sörensen, S. P. L. Ergebnisse d. Physiologie, 12, 416, 417, 1912.

[2] This will be explained further by an illustration on the following page.

[3] Bjerrum. *Ibid.*, 53, 428, 1905.

[4] W. Nernst. Zeitschr. physik. Chem., 4, 129, 1889.

Example.

t° = 19.2° C (constant during the experiment).
R_1 = 307.0 (constant reading on the bridge at five minute interval).
R = 500.2 (as above).
E. M. F. of the normal element = 1.0189.

Then the total E. M. F. of the chain can be calculated as follows: —

N.E. = normal element.
Ac. = accumulator.
x = the chain.
1000 = scale on bridge.

$$\frac{307.0}{1000} = \frac{x}{Ac.}; \quad \frac{500.2}{1000} = \frac{N.E.}{Ac.}$$

$$x = \frac{307.0\ Ac.}{1000} \qquad (1)$$

$$\frac{500.2}{1000} = \frac{N.E.}{Ac.}$$

$$Ac. = \frac{1000\ N.E.}{500.2}$$

$$= \frac{1000 \times 1.0189}{500.2} \qquad (2)$$

Substituting (2) in (1),

$$x = \frac{307.0}{1000} \times \frac{1000 \times 1.0189}{500.2}$$

$$= 0.6254 \text{ volt, which is expressed p.}$$

Substituting the value for p in the formula,

$$P_{\dot{H}} = \frac{0.525 - 0.3377}{0.0577 + 0.0002\ (19.2 - 18)}$$

$$= 4.967$$

or in terms of H ion concentration,

$$P_{\dot{H}} = 4.967 = -4.967 \text{ (log. H)}$$

$$10^{-4.967} = 1.0789 \times 10^{-5}$$

$$H = .000010789$$

Besides the apparatus[1] listed above, a H-generator was employed, which is a good-sized Kipp's generator used with a series of washing bottles and drying tube, consisting of (*a*) 30 per cent. KOH, (*b*) alkaline pyrogallic acid, (*c*) conc H_2SO_4 and soda lime in U-tube. Since a considerable amount of CO_2 is produced during the course of metabolism, the same precaution is taken as with blood. For this purpose Hasselbach's electrode with shaking arrangement is employed.

In setting up the apparatus special attention should be paid to rigidness, insulation and temperature. In order to meet with these requisites the apparatus was placed on a big central table in the laboratory. First, one dozen large glass rings of the same height were distributed over the top of the table. These supported a thick glass plate on which several blocks of paraffine for each piece of apparatus were placed. Thus it was possible to obtain a perfect insulation.

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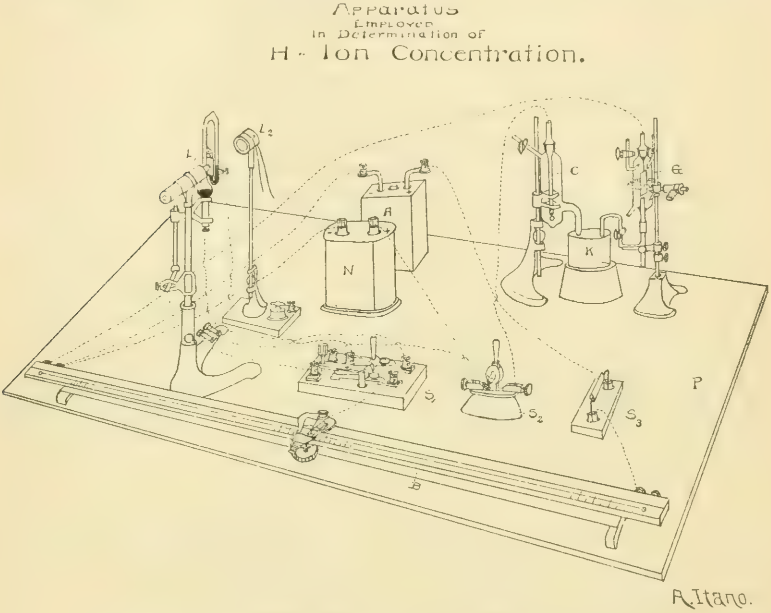
[1] This set of apparatus can be obtained from Fritz-Köhler factory in Leipzig, Germany.

In preparing the different parts of the apparatus extreme care should be exercised to obtain an accurate result. The method for the preparation of the normal element, calomel electrode, gas cell, and also calibration of the bridge wire,[1] etc., is described in detail in Findlay's "Practical Physical Chemistry." Every contact should be carefully made, so that accurate readings can be obtained. It is worthy of mention that the diffusion potential between n/10 KCl calomel electrode and the solution to be tested is reduced by interposing the saturated solution of KCl as it is indicated by K on the diagram. For the standardization of the electrode it was first platinized with general precaution; then the hydrogen ion concentration of the mixed solution (7 c. c. of m/15 KH_2PO_4, 3 c. c. of m/15 Na_2 HPO_4)[2] was determined at different intervals. After the readings became constant there was a difference of 0.0005 volts between the theoretical data and the results obtained.



DESCRIPTION OF DIAGRAM.

L_1 — Lippmann's capillarimeter.
L_2 — Tungston lamp.
A — Accumulator.
N — Western normal element.
S_1 — Switch with quick short circuiting key.
S_2 — Three-way switch.
S_3 — Two-way switch.
C — Calomel electrode.
K — Concentrated KCl cup.
G — Gas cell.
B — Bridge.
P — Thick glass plate.

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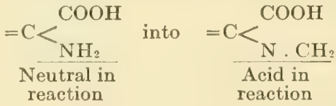
[1] The author is greatly indebted to Professor Thompson, department of physics, Amherst College, for his kind advice.

[2] Sörensen's standard solutions.

Methods for Quantitative Determination of Proteolysis.

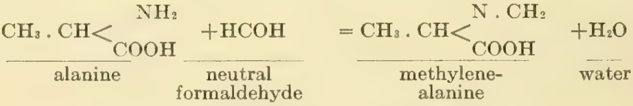
Previous to the recent development of protein chemistry and methods for the determination of cleavage products of proteins, the quantitative determination of proteolysis was not successful. With Hlaswetz and Habermann's[1] successful researches, and the investigations of Kossel and Kutscher,[2] together with the remarkable findings of E. Fischer,[3] Abderhalden,[4] Plimmer[5] and other recent workers, the chemical nature of proteins began to assume more definite form. Then several methods for determining cleavage products were advanced. Since the proteolysis is mainly the hydrolytic splitting of proteins, the degree of proteolysis can be followed quantitatively by determining the amount of the cleavage products from time to time. It is most important for our purpose to find a method which enables us to determine the amino acids as a group, because we naturally expect the amino acids as extended cleavage products. Sörensen's formol titration method[6] has been selected for this purpose. This has been done only after reviewing Hausmann and Osborn's,[7] as well as Van Slyke's methods.[8] Sörensen's method has decided advantages in ease of manipulation and accuracy when properly employed.

Theoretical Discussion of Formol Titration. — The reaction taking place between formaldehyde and amino acids, as well as its application to the quantitative determination of amino acids, was first shown by Hugo Schiff.[9] The formaldehyde converts the radical



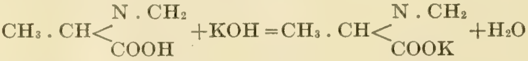
$$\underbrace{=C<{}^{COOH}_{NH_2}}_{\text{Neutral in reaction}} \quad \text{into} \quad \underbrace{=C<{}^{COOH}_{N\,.\,CH_2}}_{\text{Acid in reaction}}$$

For example: —



$$\underbrace{CH_3\,.\,CH<{}^{NH_2}_{COOH}}_{\text{alanine}} \;+\underbrace{HCOH}_{\text{neutral formaldehyde}} = \underbrace{CH_3\,.\,CH<{}^{N\,.\,CH_2}_{COOH}}_{\text{methylene-alanine}} \;+\underbrace{H_2O}_{\text{water}}$$

That is, the addition of neutral formaldehyde to the practically neutral solution of alanine, which can be titrated with the standardized alkaline solution in accordance with the following equation: —



$$CH_3\,.\,CH<{}^{N\,.\,CH_2}_{COOH} + KOH = CH_3\,.\,CH<{}^{N\,.\,CH_2}_{COOK} + H_2O$$

That is, a simple neutralizing reaction.

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[1] Ann. (Leipzig), 169, 150, 1873.

[2] Zeit. Physiol. Chem., 22, 176, 1896–97; 25, 165, 1895.

[3] Untersuchungen über Aminosäuren, Polypeptide und Proteins, Berlin, 1906.

[4] Abderhalden, E. Lehrbuch d. Physiologischen Chemie, Teil 1, 307–652, 1914.

[5] Plimmer, R. H. The Chemical Constituent of the Proteins, Monograph on Biochemistry.

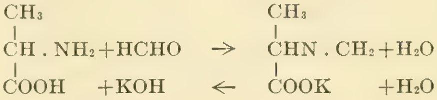
[6] Sörensen, S. P. L. Comptes Rendus 7me. Ire Livraison, 1907.

[7] Zeit. Physiol. Chem., 27, 95, 1899; 29, 136, 1900.

[8] Proc. Soc. Exp. Biol. and Med., 7, 46, 1910; Berichte d. D. Chem. Ges., 43, 3170, 1910.

[9] Schiff, H. Ann. der Chemie, 310, 25, 1899; 319, 59 et 289, 1901; 325, 348, 1902.

Schiff studied further to apply this reaction to the quantitative determination of amino acids, polypeptides and other similar compounds. His attempt was not wholly successful because he neglected to consider all factors involved in the process. For instance, the amount of potassium hydroxide, water and other substances which are used in the titration should be considered in order to obtain accurate results. This was shown by Sörensen, who pointed out the reversibility of such a reaction as is indicated below: —



$$\begin{array}{lcl} CH_3 & & CH_3 \\ | & & | \\ CH\,.\,NH_2 + HCHO & \rightarrow & CHN\,.\,CH_2 + H_2O \\ | & & | \\ COOH \quad + KOH & \leftarrow & COOK \quad\quad + H_2O \end{array}$$

He also found that the equilibrium of the system depends upon the quantity of each of the chemicals present. For example, from the above reaction it can be clearly seen that an increase of potassium hydroxide, or, in other words, of hydroxyl ions, in the system would result in an action similar to an increase of the formaldehyde. In order to control these sources of error, Sörensen chose an indicator which turns with such a high concentration of hydroxyl ions that the process could be finished from left to right. He used phenolphthalein and titrated to a strong red color with n/5 KOH. Thus he studied the method very carefully, and succeeded in conducting it with such precision that he had only 0–5 per cent. error when he observed certain conditions which will be enumerated in an example to be cited soon.

Further, Sörensen extended the formol titration method to proteolysis, and found that it can be depended upon for accurate quantitative determinations. He based his principle upon the fact that proteolysis is mainly the hydrolytic splitting of protein, and takes place by the addition of a water molecule. It is a differential method as illustrated below: —

$X - Y = Z$, where X is amount of amino acids present after proteolysis takes place; Y, the same, before; Z the same produced by the proteolysis.

In order to carry out the determination, all other acids in the liquid should be eliminated; that is, the liquid must contain as many H ions as OH ions at the beginning. If all these precautions are observed the amount of alkali used in the titration after the addition of neutral formaldehyde should be equal to the amount of the amino acid group present. After finding X and Y, Z, or the index of degree of proteolysis, can be determined.

Example.

Preparation of Solutions and Reagents.

(*a*) 125 c. c. 4 per cent. Witte's peptone solution
75 c. c. 0.2 per cent. pancreatin solution
50 c. c. distilled water
} total volume, 250 c. c.

(*b*) Standard acid solution: n/5 HCl is prepared by standardizing against sodium oxalate which is obtained from the Bureau of Standards.

(*c*) Standard alkali solution: n/5 KOH is prepared by titrating against the above standard acid.

(*d*) Indicators: (1) Phenolphthalein — dissolve 0.5 gram of phenolphthalein in 500 c. c. alcohol and make it to a liter. (2) Litmus paper — a narrow strip of Kahlbaum litmus paper.

(*e*) Reagents: (1) Neutral formaldehyde — 50 c. c. of 40 per cent. commercial formaldehyde with 1 c. c. of the phenolphthalein is neutralized to rose color. (2) Bismark-brown, tropæolin 0 and 00 and methyl violet — these reagents are prepared by dissolving 0.2 gram of the substance in one liter of water.

(*f*) Water; carbon dioxide and ammonia-free distilled water. This is prepared with usual precautions.

(*g*) Test solution. This is prepared with equal portions of m/15 KH_2PO_4 and m/15 Na_2HPO_4, and is perfectly neutral.

Determination.

I. Right after the preparation of solution (*a*): —

Transfer 20 c. c. of the water (*g*) into a 50 c. c. flask and the same amount of the solution (*a*) into another. Adjust the color of the water to the latter by adding about 2 drops of bismark-brown in this case, and use any one of the mixtures of tropæolin 0 and 00 or methyl violet to obtain a comparative coloration; neutralize it to litmus, controlling the neutralization point by means of the test solution. Add 10 c. c. of the neutral formaldehyde. Titrate it to a dark red color with the standard alkali, and titrate it back to strong red color with the standard acids. Record the number of c. c. of standard acid and alkali used. Treat the flask with the solution (*a*) in the same manner, except adjusting the coloration. After titrating it to dark red color titrate it back to its former color with (*a*).

Results.

	Control (water).	Sample (peptone solution).
Number of c. c. used n/5NaOH	1.20 c. c.	3.35 c. c.
Number of c. c. used n/5 HCl	1.10	.33
	0.10 n/5 NaOH	3.02
		.10 (control)
		2.92 n/5 naOH

Since

1 c. c. n/5 NaOH = 2.8 milligrams of amino nitrogen,

$2.92 \times 2.8 \doteq 8.176$ milligrams amino nitrogen in 20 c. c. of the solution. This is designated as Y in the above equation.

II. After fifteen hours incubation at 40° C.: —

The rest of the solution (*a*) was placed in incubator at 40° C. right after 20 c. c. had been taken out for the above determination, and was kept there for sixteen hours. At the end of that period 20 c. c. of the solution was drawn out for titration, and treated in the same manner.

Results.

	Control.	Sample.
Number of c. c. NaOH	1.8	8.15
Number of c. c. HCl	0.1	.10
	1.7 n/5 NaOH	8.05
		1.70 (control)
		6.35 c. c. n/5 NaOH

$6.35 \times 2.8 = 17.780$ milligrams of amino nitrogen. This is indicated as X.

$X - Y = Z.$

$17.780 - 8.176 = 9.604$ milligrams of amino nitrogen was produced by proteolysis during the sixteen hours' incubation.

Thus, the proteolysis can be followed from time to time.

In applying this method in the present investigation it may be clearly seen from the preceding discussions that the proteolysis can be followed accurately by determining the difference between the amount of amino acid present in the original culture medium and after the growth of an organism in it. It is, however, necessary to exercise special care in regard to the presence of ammonia and carbon dioxide, produced in the course of deamidation, which interferes with the determination. To avoid these sources of error ammonia and carbon dioxide-free air was passed through the media, which were made alkaline by the addition of n/1 NaOH previous to determination.

Preparation of Media.

Steps in Selection of Medium.

Common experiences dictate that the properties of media are influenced by constituents and technic of preparation. To obtain stable and comparable data is essential in these investigations from the standpoint of biology, chemistry and physics because a very slight variation will furnish unsatisfactory results. Several media were carefully tested.

Medium I.: —
1,000 grams chopped lean beef.
1,000 c. c. distilled water.

Medium II.: —
1 per cent. Liebig's meat extract.
1,000 c. c. distilled water.

Medium III.: —
1 per cent. Witte's peptone.
0.5 per cent. NaCl.
1,000 c. c. distilled water.

Medium IV.: —
1 per cent. Liebig's meat extract.
1 per cent. Witte's peptone.
0.5 per cent. NaCl.
1,000 c. c. distilled water.

The method of preparation and testing is outlined below.

Medium I. — Five hundred grams of chopped lean beef were obtained from a local meat market and immediately well mixed. Ten lots of 30 grams each were weighed out and each lot was transferred into a 250 cubic centimeter Erlenmeyer flask. These flasks were marked *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k* and *l*, and divided into groups, one *a* to *f*, inclusive, marked A, and the other, *g* to *l*, inclusive, marked B. Group A was treated directly, while group B was placed in an incubator at 37° C. for twenty-four hours. After an addition of 300 cubic centimeters of distilled water to the former the flasks were shaken for thirty minutes. At the end of this period the extract was prepared from flask *a* by straining through two layers of cheesecloth and filtering through Swedish filter paper. This extract will be designated as "original" in Table I. The remaining flasks were placed in a water bath at 40° C. and kept for forty minutes with frequent stirring. Flask *b* was then removed, and the extract was prepared in the same manner as the "original." Flasks *c*, *d*, *e* and *f* were brought to the boiling point. Flask *c* was removed at the end of ten minutes, *d* at the end of thirty minutes, *e* at the end of forty-five minutes and *f* at the end of sixty minutes. Each extract was prepared after careful counterweighing. The foregoing extracts were used for further study. After twenty-four hours incubation at 37° C. group B was treated identically as group A.

Medium II. — In this medium Liebig's meat extract was used instead of fresh lean beef, and three separate lots were prepared, namely, A, B and C. Lot A was prepared by taking 2 grams of Liebig's meat extract secured from one jar; B, the same amount of the meat extract from a second jar; and C, the same amount, from a third jar. The object of preparing lots A, B and C in Medium II. was to measure any difference which might exist among the containers of Liebig's meat extract. The preparation of these lots from this point is identical. To each, 200 cubic centimeters of distilled water were added and the whole shaken for thirty minutes. At the end of this time, 30 cubic centimeters of the mixture were removed from each flask. The rest was then immersed in the water bath at 40° C. for forty-five minutes. Again 30 cubic centimeters of the mixture were taken out from each. The remainder was then brought to the boiling point and held for ten, forty-five and sixty minutes, 30 cubic centimeters of the mixture being removed at the end of each period. After each operation the flask was carefully counterweighed.

Medium III. — In this medium two separate lots, namely, A and B, were prepared. Ten grams of Witte's peptone obtained from each of two different bottles were used, respectively, for lots A and B. By this means it was hoped to note any difference existing in Witte's peptone taken from different containers. The preparation of A and B from this point on is identical. After 5 grams of NaCl had been added to each, a paste was made with 50 cubic centimeters distilled water. The whole was then made up to one liter. This was shaken for thirty minutes and treated in the same manner as Medium II., with these exceptions: 100 cubic centimeters were heated in an autoclave for thirty minutes under 15 pounds' pressure; 300 cubic centimeters were subjected to fractional sterilization for fifteen minutes on three successive days.

Medium IV. — In this medium three separate lots, namely, A, B and C, were made up at three different times from the same materials. These different lots were prepared and treated alike, as follows: 10 grams Liebig's meat extract were dissolved in 500 cubic centimeters distilled water. This was thoroughly shaken for thirty minutes. At the same time, 10 grams of Witte's peptone and 5 grams NaCl were mixed separately into a smooth paste with 200 cubic centimeters distilled water, and the volume was made up to 500 cubic centimeters. This was shaken for thirty minutes. These two portions were then mixed thoroughly and treated in the same manner as Medium III., with the following additional physical determinations, namely, osmotic pressure, viscosity, surface tension and specific conductance. Such determinations were made by taking samples after subjecting the mixture to the autoclave. In addition to these, the total nitrogen was determined by the Kjeldahl method. The results will be given in Table I.

TABLE I. — *Experiment with Different Media.*

MEDIA.			TREATMENT.										PHYSICAL PROPERTIES.				
					BOILING.				AUTOCLAVE.	FRACTIONAL STERILIZATION.			a	b	c		
No.	Lot.	Properties.	Original.	40 Minutes at 40° C.	10 Minutes.	30 Minutes.	45 Minutes.	60 Minutes.	30 Minutes.	First Day.	Second Day.	Third Day.	Osmotic Pressure.	Viscosity.	Surface Tension.	Specific Conductance.	Growth.
I.	A.	P_H	5.45	5.47	5.50	5.71	5.72	5.72	-	-	-	-	-	-	-	-	-
		F.N.	58.80	65.40	75.30	74.20	75.30	77.00	-	-	-	-					
	B.	P_H	5.37	5.47	5.44	5.68	5.56	5.52	-	-	-	-					
		F.N.	137.50	142.70	146.00	151.10	163.00	178.10	-	-	-	-					
II.	A.	P_H	5.54	5.74	5.77	5.79	5.71	5.71	-	-	-	-	-	-	-	-	-
		F.N.	19.60	26.60	28.00	29.40	30.80	32.20	-	-	-	-					
	B.	P_H	5.59	5.71	5.64	5.77	5.72	5.79	-	-	-	-					
		F.N.	19.40	25.20	26.60	30.80	30.81	32.20	-	-	-	-					
	C.	P_H	5.58	5.72	5.79	5.72	5.79	5.71	-	-	-	-					
		F.N.	22.40	26.60	26.40	32.20	32.30	32.30	-	-	-	-					

III.	A.	$P_{\dot{H}}$	6.88	6.66	6.90	6.82	6.92	6.92	6.91	6.92	6.90	6.91	-	-	-	-	-
		O.T.	0.60	0.65	0.62	0.60	0.58	0.60	0.70	0.65	0.62	0.65					
		F.N.	11.20	27.30	36.40	36.40	39.40	39.40	38.80	37.80	40.00	39.40					
	B.	$P_{\dot{H}}$	6.79	6.90	6.65	6.86	6.91	6.90	6.87	6.89	6.90	6.87					
		O.T.	0.58	0.61	0.60	0.62	0.65	0.60	0.64	0.60	0.59	0.62					
		F.N.	11.60	29.20	35.00	37.50	39.00	39.50	39.20	38.00	39.00	38.00					
IV.	A.	$P_{\dot{H}}$	6.12	6.35	6.13	6.12	6.22	6.16	6.17	6.15	6.12	6.21	6.694	1.155	0.9089	14.40×10^{-8}	Abundant.
		O.T.	2.10	2.25	2.15	2.30	2.10	2.25	2.15	2.30	2.20	2.20					
		T.N.	232.0	-	-	-	-	-	-	-	-	-					
		F.N.	29.40	31.60	32.20	32.20	44.80	46.20	46.20	47.60	48.20	47.60					
	B.	$P_{\dot{H}}$	6.15	6.12	6.31	6.16	6.15	6.12	6.15	6.16	6.12	6.16	6.653	0.150	0.9030	14.35×10^{-8}	Abundant.
		O.T.	2.20	2.15	2.30	2.25	2.20	2.15	2.20	2.10	2.35	2.25					
		T.N.	225.0	-	-	-	-	-	-	-	-	-					
		F.N.	29.50	29.40	30.16	32.60	43.60	47.60	46.20	46.20	47.60	46.50					
	C.	$P_{\dot{H}}$	6.16	6.25	6.12	6.15	6.16	6.26	6.15	6.16	6.21	6.22	6.673	1.148	0.9090	14.20×10^{-8}	Abundant.
		O.T.	2.10	2.15	2.35	2.25	2.30	2.35	2.15	2.30	2.20	2.20					
		T.N.	228.5	-	-	-	-	-	-	-	-	-					
		F.N.	31.60	32.20	32.50	33.60	46.20	47.60	44.80	49.00	50.20	50.10					

$P_{\dot{H}}$ — Exponent of Hydrogen Ion Concentration.
O.T. — Ordinary titration (Fuller's scale).
T.N. — Total nitrogen (mg. per 100 c. c.).
F.N. — Formol titrating nitrogen (mg. per 100 c. c.).
(*a*) — In term of atmospheric pressure; (*b*) and (*c*) — water as 1.

SUMMARY OF TABLE I.

Medium I.

Lots A and B. — Table I. indicates an increase in both P_H and the amount of the formol titrating nitrogen as the treatment continued. The decrease in the hydrogen ion concentration may be due to the volatility of an organic acid, and the increase of the formol titrating nitrogen is apparently caused by hydrolysis in the course of treatment. These changes became constant after the media were boiled for forty-five minutes or longer. On the other hand, there is a marked difference between lots A and B from the standpoint of the hydrogen ion concentration and the amount of the formol titrating nitrogen; especially, the amount of the formol titrating nitrogen in lot A is much greater than in lot B. This is very interesting, because it indicates the possible existence of such variation in the same lot of chopped lean beef.

Medium II.

Lots A, B and C. — The same changes occurred in each lot as in Medium I., namely, a decrease of hydrogen ion concentration and an increase of the formol titrating nitrogen. The variations among the lots A, B and C were slight, however. This indicates that Liebig's meat extract from different jars gives fairly uniform results.

Medium III.

Lots A and B. — The same changes were observed in this medium as in Medium II. It is also seen that the properties of the medium became almost constant after it was autoclaved. Both lots A and B agree with each other very closely. Significantly the rate of increase of the formol titrating nitrogen is very marked in this medium.

Medium IV.

Lots A, B and C. — The same phenomena were observed in this medium as in the others. After their properties became uniform there was very slight variation among them.

Biologic Test of Medium IV. — After it was found that Medium IV. gave uniform results chemically and physically, an approximate biologic test was applied macroscopically in the following manner. Two test tubes for each lot were prepared and filled with 10 cubic centimeters of the medium, respectively. They were then sterilized. One test tube from each lot was kept for control, and the other was inoculated with *B. subtilis.* They were placed in the incubator at 37° C., and an observation was made each day for six successive days.

TABLE II. — *Growth of B. Subtilis in Medium IV.*

	24 Hours.	48 Hours.	72 Hours.	96 Hours.	120 Hours.	144 Hours.
Lot A: —						
Control,	—	—	—	—	—	—
Culture,	+	++	+++	+++	+++	+++
Lot B: —						
Control,	—	—	—	—	—	—
Culture,	+	++	+++	+++	+++	+++
Lot C: —						
Control,	—	—	—	—	—	—
Culture,	+	++	+++	+++	+++	+++

— indicates no growth.
+indicates slight growth.
++ indicates strong growth.
+++ indicates abundant growth.

So far as the macroscopical examination was concerned abundant and uniform growth took place in each lot.

Medium IV., having satisfied the chemical, physical and biological tests better than Medium I., II. and III., and being in regular use in microbiologic work, it appeared as suitable as any for the investigation under way.

Preparation of Media of Different Hydrogen Ion Concentration.

In the previous experiment Medium IV. was found to be satisfactory so far as it had been investigated. It is now necessary to adjust its reaction by the addition of acid or alkali, so that a series of the medium of various hydrogen ion concentrations, viz., $P_{\dot{H}} = 1$ to 13, may be obtained. Only thus can it be employed to accomplish the purpose of the proposed investigation.

It is not an easy task, however, to secure such a series of hydrogen ion concentrations in such a medium, because the presence of amphoteric substances and mechanical factors involved in the course of preparation should be taken into consideration. First, to obtain the approximate amount of acid or alkali to be added the colorimetric method was resorted to.

The Colorimetric Method.[1] — On the one hand is the medium, on the other the standard solution of known hydrogen ion concentration. An organic dye that changes color with a variation in the amount of hydrogen ion concentration is employed as an indicator. The indicator is added to the standard solution, as well as the sample medium for comparison of colors. An estimate of the hydrogen ion concentration is made possible by this means.

Concretely: To ascertain the hydrogen ion concentration, 5 drops of methyl red[2] were added to 10 cubic centimeters of Medium IV. A yellowish green color was observed. Since methyl red gives this color in a solution in which hydrogen ion concentration is greater than $P_{\dot{H}} = 6$, this medium must contain more than $P_{\dot{H}} = 6$. To make the determination more exact, several standard solutions were prepared, and the colors produced with the indicator were traced to identical shades alike in standard solution and medium. Mixing m/15 KH_2PO_4 and m/15 Na_2HPO in various proportions, as in the table below, the different hydrogen ion concentrations ranging from $P_{\dot{H}} = 6.24$ to $P_{\dot{H}} = 7.35$ were obtained.

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[1] Sörensen, S. P. L. Compt. rend. du Lab. de Carlsberg, 8, 1, 1909, 67.

[2] Prepared according to S. P. L. Sörensen.

TABLE III. — *Standard Solution of Different* $P_{\dot{H}} = (6.24\text{–}7.35)$.

NUMBER OF TEST TUBE.	Number of Cubic Centimeters of m/15 KH_2PO_4.	Number of Cubic Centimeters of m/15 Na_2HPO_4.	$P_{\dot{H}} = x$.
1,	5	5	6.81
2,	6	4	6.98
3,	7	3	7.15
4,	8	2	7.35
5,	4	6	6.65
6,	3	7	6.47
7,	2	8	6.24

m = molecular.

Before an indicator[1] is added to the standard solution, it is important to adjust the color of the standard solution itself to the identical color of the medium. If this adjustment is neglected it is impossible to compare the color produced in each, upon the addition of the indicator. For this purpose 4 drops of tropæolin 0, as previously suggested, and the same amount of methyl violet, gave an almost identical color upon very careful comparison. Finally, 10 drops of neutral red[2] were added to both the standard solution and the medium. Then the color was compared by the usual method, and it was found that the color of the medium corresponded to the color which was intermediate between tubes No. 6 and No. 7, or approximately $P_{\dot{H}} = 6.35$. Therefore Medium IV., without any addition of either acid or alkali, contained $P_{\dot{H}} = 6.35$ according to the findings of this method.

An attempt was next made to prepare a series of $P_{\dot{H}} = 2$, 4, 8 and 10, after finding the $P_{\dot{H}}$ in the medium by adding various amounts of n/5 HCl and n/5 NaOH, so that other $P_{\dot{H}}$ can be obtained by interpolation. For this purpose 10 cubic centimeters of the medium was taken and treated as in the preceding processes, except that a suitable standard solution and indicators for the different $P_{\dot{H}}$ were used.

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[1] In this case neutral red which gives a rosy red to orange colors within the range from $P_{\dot{H}} = 6$ to $P_{\dot{H}} = 10$.

[2] Prepared according to S. P. L. Sörensen.

TABLE IV. — *Preparation of Different* $P_{\dot{H}} = (2, 4, 8 \text{ and } 10)$.

Desired P_H	Mixture of Standard Solution.	Coloring Substance.	Indicator.	Number of Cubic Centimeters of n/5 HCl or n/5 NaOH added per 10 c. c. of the Medium.
2, .	3.5 c. c. m/10 citrate and 6.5 c. c. n/10 HCl	4 drops each of tropæolin and methyl violet	5 drops tropæolin 00	3.4 c. c. n/5 HCl
	3 c. c. m/10 citrate and 7 c. c. n/10 HCl	4 drops each of tropæolin and methyl violet	5 drops tropæolin 00	
4, .	5 c. c. m/10 citrate and 5 c. c. n/10 HCl	4 drops each of tropæolin and methyl violet	4 drops methyl red	0.75 c. c. n/5 HCl
	6 c. c. m/10 citrate and 4 c. c. n/10 HCl	4 drops each of tropæolin and methyl violet	4 drops methyl red	
8, .	2 c. c. borate and 8 c. c. boric acid	4 drops each of tropæolin and methyl violet	8 drops naphtolphthalein	0.28 c. c. n/5 NaOH
	3 c. c. borate and 7 c. c. boric acid	4 drops each of tropæolin and methyl violet	8 drops naphtolphthalein	
10, .	6 c. c. borate and 4 c. c. n/10 NaOH	4 drops each of tropæolin and methyl violet	5 drops thymolphthalein	0.6 c. c. n/5 NaOH
	7 c. c. borate and 3 c. c. n/10 NaOH	4 drops each of tropæolin and methyl violet	5 drops thymolphthalein	

Table IV. indicates that 3.4 cubic centimeters of n/5 HCl per 10 cubic centimeters of the medium is necessary to secure $P_{\dot{H}} = 2$ approximately; 0.75 cubic centimeters of n/5 HCl for $P_{\dot{H}} = 4$; 0.28 cubic centimeters of n/5 NaOH for $P_{\dot{H}} = 8$; and 0.6 cubic centimeters n/5 NaOH for $P_{\dot{H}} = 10$.

The media, which have been prepared, differ in their total volume; consequently, the concentration of the media differ from each other. Again, the author observed that after subjecting these media to sterilization, on the addition of the required amount of acid and alkali, both $P_{\dot{H}}$ and the amount of formol titrating nitrogen in the media varied widely, as indicated in Table V: —

TABLE V. — *The Influence of Sterilization on $P_{\dot{H}}$ and the Formol Titrating Nitrogen.*

	$P_{\dot{H}}$		FORMOL TITRATING NITROGEN (MG. PER 100 CUBIC CENTIMETERS MEDIUM).	
	Before Sterilization.	After Sterilization.	Before Sterilization.	After Sterilization.
Desired,	found	found	found	found
Control,[1]	6.40	6.55	46.70	47.45
2,	1.80	2.35	47.20	60.50
4,	3.75	4.20	47.15	56.65
8,	8.10	8.45	46.90	51.45
10,	9.85	10.15	47.10	54.30

[1] Medium IV. without addition of acid and alkali.

From Table V. it is evident that a general increase of $P_{\dot{H}}$ took place in each medium, and it is least in the control; the marked and varied increase of the formol titrating nitrogen in each medium occurred and the change is parallel to the amount of the acid and alkali added. These changes may be attributed to the different amounts of acid and alkali added, the heat caused by the sterilization, and the variation in the original concentration.

In order to eliminate these sources of error, and to secure more uniformity in the media, the author resorted to the following procedure: instead of preparing Medium IV. as just stated, it was made up according to the following formula: —

2 per cent. Liebig's meat extract.
2 per cent. Witte's peptone.
1 per cent. NaCl.
1,000 c. c. distilled water.

This medium has been used for the preparation of different $P_{\dot{H}}$, as the formula indicates below.

$$\underbrace{\frac{X}{2}}_{\text{Number of c. c. of the above medium}} + \underbrace{Y}_{\text{Required number of c. c. n/5 HCl or n/5 NaOH}} + \underbrace{\left(\frac{X}{2} - Y\right)}_{\text{Number of c. c. } H_2O \text{ to make up to the total volume}} = \underbrace{X}_{\text{Total volume}}$$

of which

X is the total volume of the medium which has the same constituents as Medium IV.

Y is the required amount of n/5 HCl or n/5 NaOH which has been determined to secure different $P_{\dot{H}}$.

These different constituents were sterilized separately before mixing. The medium which was thus prepared maintains the figured $P_{\dot{H}}$ fairly closely, and also the amount of formol titrating nitrogen becomes uniform, as shown below.

TABLE VI. — *Addition of Acid and Alkali to the Medium, and their Influence upon the Formol Titrating Nitrogen.*

$P_{\dot{H}}$ desired.	$P_{\dot{H}}$ Approximate Colorimetric.	Number of Cubic Centimeters Medium.	Number of Cubic Centimeters n/5 HCl or n/5 NaOH.	Number of Cubic Centimeters H_2O.	Total Volume.	$P_{\dot{H}}$ found Electrometric.	Milligrams of Formol Titrating Nitrogen.
2,	2	5	n/5 HCl 3.40	1.60	10	1.357	47.70[1]
4,	4	5	0.75	4.25	10	3.559	47.50
8,	8	5	n/5 NaOH 0.28	4.72	10	8.245	47.60
10,	10	5	0.60	4.40	10	9.788	47.40

[1] Milligrams in 100 cubic centimeters broth.

The results indicate that the two methods, colorimetric and electrometric, give better comparative results where $P_{\dot{H}}$ is greater than 6, or directed toward alkalinity. There is, however, a marked difference when it is directed toward acidity. This may be due to the nature of the indicators used. Again, this last experiment was carried out making the total volume to 10, while the amount of n/5 HCl and n/5 NaOH was determined previously by adding a certain amount of the acid or alkali to 10 cubic centimeters. These factors undoubtedly influenced the results to some extent. In the preparation of the medium used for the proposed investigation, all these factors and precautions have been observed.

Besides these, still another factor has been taken into consideration in carrying out this investigation. The amount of medium added at the time of inoculation may influence the results.

TABLE VII. — *Final Preparation of the Medium of Different* $P_{\dot{H}}$ *= (1–13).*

Desired $P_{\dot{H}}$	Found $P_{\dot{H}}$	Number of					Total.	Milligram F. N. in 100 Cubic Centimeters.
		Cubic Centimeters 2X Medium.	Cubic Centimeters Inoculation.	Cubic Centimeters n/1 HCl.	Cubic Centimeters n/1 NaOH.	Cubic Centimeters H_2O.		
Control, .	5.65	200.0	–	–	–	200.0	400.0	44.80
1, . .	0.86	199.0	1	41.0	–	159.0	400.0	46.20
2, . .	1.86	199.0	1	25.6	–	174.4	400.0	47.60
3, . .	2.62	199.0	1	13.0	–	187.0	400.0	46.20
4, . .	4.18	199.0	1	6.0	–	194.0	400.0	47.60
5, . .	4.82	199.0	1	2.2	–	197.8	400.0	46.20
6, . .	5.42	199.0	1	–	0.5	197.5	400.0	47.20
7, . .	6.66	199.0	1	–	4.0	196.0	400.0	47.60
8, . .	8.17	199.0	1	–	8.0	192.0	400.0	47.60
9, . .	9.43	199.0	1	–	12.0	188.0	400.0	46.20
10, . .	10.47	199.0	1	–	16.0	184.0	400.0	47.60
11, . .	11.22	199.0	1	–	20.0	180.0	400.0	47.60
12, . .	11.60	199.0	1	–	24.0	176.0	400.0	49.00
13, . .	12.80	199.0	1	–	28.0	172.0	400.0	49.00

2X indicates the medium of double concentration.
F.N. indicates the formol titrating nitrogen.

In this preparation n/1 HCl and n/1 NaOH were used instead of n/5 because it appears that the smaller the quantity the easier the manipulation and the greater the accuracy. The results thus obtained are fairly satisfactory.

In flasks 4 and 5 the contents became turbid with the addition of the n/1 acid, while all others remained clear. This turbidity may be due to the precipitation of meta-protein or some other similar substance.

ACCLIMATIZATION OF THE CULTURE.

In general bacteriology it is commonly recognized that environment exerts a great influence upon the physiologic function and morphology of microörganisms. To secure an organism of constant habits the author resorted to the following procedure: —

Six flasks containing 25 cubic centimeters of Medium IV. ($P_{\dot{H}} = 6.80$) were prepared. One of these was inoculated with *B. subtilis* which was obtained from the American Museum of Natural History, New York. After maintaining this flask at 37° C. for twenty-four hours, subinoculation from it was made into another flask of the same lot as above, by means of a platinum loop. This process of subinoculation was continued from one flask to another every twenty-four hours, until the fifth flask had been inoculated and incubated. From this flask a platinum loopful of the culture was transferred into a dilution flask, which contained 500 cubic centimeters of the same medium. At the same time, three agar plates were made by placing a loopful from the dilution into the first agar tube, and from the first agar tube to the second, and from the second to the third. After these plates had developed for forty-eight hours at 37° C., one entire colony of a medium size was selected and transferred into the sixth flask of the above series by means of a small platinum spatula. This flask had been placed in the incubator for twenty-four hours at 37° C. before using it for inoculation.

INOCULATION OF MEDIA.

Each of a series of flasks (1 to 13), already prepared and containing 399 cubic centimeters of Medium IV. of various P$_{\dot{H}}$, was inoculated with 1 cubic centimeter of the acclimatized culture. These flasks were then placed in the incubator at 37° C. Waxed paper had been placed over the cotton plug and bound by a rubber band for protection against evaporation. Samples of 50 cubic centimeters for determinations were removed from time to time by means of a sterilized pipette.

RESULTS.

TESTING THE VITALITY OF THE ORGANISM.

Hydrogen ion concentration has a decidedly inhibitory and lethal influence upon microörganisms; accordingly, a crude test was introduced to follow this. Streak cultures on an agar plate were made at each determination of the hydrogen ion concentration.

TABLE VIII. — *Test for Vitality.*

NUMBER OF FLASK.	Original.	24 Hours.	48 Hours.	96 Hours.	144 Hours.	192 Hours.	240 Hours.
Control,	—	—	—	—	—	—	—
1,	—	—	—	—	—	—	—
2,	—	—	—	—	—	—	—
3,	—	—	—	—	—	—	—
4,	—	—	—	—	—	—	—
5,	+	+	+	+	+	+	+
6,	+	+	+	+	+	+	+
7,	+	+	+	+	+	+	+
8,	+	+	+	+	+	+	+
9,	—	—	+	+	+	+	+
10,	—	—	—	—	—	—	—
11,	—	—	—	—	—	—	—
12,	—	—	—	—	—	—	—
13,	—	—	—	—	—	—	—

— no growth.
+ positive growth.

Table VIII. indicates that flasks 5, 6, 7 and 8 proved to be positive from the beginning, while all others were negative, except flask 9, which test gave negative results before forty-eight hours, then became positive. This change may be attributed to inhibitory action.

Determination of the Rate of Growth.

It was found desirable to determine the rate of growth as well as the different hydrogen ion concentrations. This was done by comparing growth turbidity.

Immediately after inoculation, 10 cubic centimeters of the contents of each flask of the set 1 to 13 was transferred into a corresponding set[1] of test tubes of uniform diameter. These test tubes were kept as the standard by the addition of thymol, and protected from evaporation by means of rubber stoppers. At each determination the same amount of a well-mixed sample was transferred from each flask into another set of corresponding test tubes, and the turbidity compared with the standard. The results are here recorded.

Table IX. — *Rate of Growth.*

Number of Flask.	Original.	24 Hours.	48 Hours.	96 Hours.	144 Hours.	192 Hours.	240 Hours.
Control,	—	—	—	—	—	—	—
1,	—	—	—	—	—	—	—
2,	—	—	—	—	—	—	—
3,	—	—	—	—	—	—	—
4,	—	—	—	—	—	—	—
5,	—	+	++	++	+++	+++	+++
6,	—	++	++	+++	+++	+++	+++
7,	—	++	+++	+++	+++	+++	+++
8,	—	+	++	++	+++	+++	+++
9,	—	—	+	+	++	+++	+++
10,	—	—	—	—	—	—	—
11,	—	—	—	—	—	—	—
12,	—	—	—	—	—	—	—
13,	—	—	—	—	—	—	—

— no growth.
+ slight growth.
++ strong growth.
+++ abundant growth.

Table IX. indicates that after twenty-four hours a fairly strong growth took place in flasks 6 and 7, and slight growth in flasks 5 and 8. It was after forty-eight hours that the growth was first observed in flask 9. All other flasks proved to be negative.

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[1] It was necessary to prepare a separate standard for each flask, because flasks 4 and 5 became turbid on addition of acid, as previously stated.

DETERMINATION OF THE RATE OF PROTEOLYSIS.

The rate of proteolysis in media of different hydrogen ion concentration stands as one of the most important phases of this investigation. The method and also an example of such a determination has been treated previously. The results will be given in terms of milligrams per 100 cubic centimeters of the medium (Table X. and Graph 1).

TABLE X. — *Following the Proteolytic Activity.*

NUMBER OF FLASK.	Original.	24 Hours.	48 Hours.	96 Hours.	144 Hours.	192 Hours.	240 Hours.
Control,	44.80[1]	46.20	47.60	48.90	49.80	50.20	50.80
1,	46.20	49.10	51.80	53.20	53.60	54.20	54.60
2,	47.60	50.40	53.20	54.60	56.00	57.40	57.40
3,	46.20	51.80	50.40	51.60	53.20	56.00	57.40
4,	47.60	46.20	47.60	50.40	53.20	53.20	54.60
5,	46.20	50.60	56.00	65.80	82.60	119.00	147.60
6,	47.20	54.60	60.20	82.60	117.60	142.80	152.50
7,	47.60	56.00	61.60	84.00	113.40	138.60	149.60
8,	47.60	49.10	54.00	69.80	89.60	129.40	137.20
9,	46.20	47.60	50.90	56.20	62.00	67.20	95.20
10,	47.60	49.00	49.00	53.20	57.40	57.60	58.80
11,	47.60	49.00	50.40	53.20	53.60	56.00	57.40
12,	49.00	50.40	51.80	51.60	57.40	58.80	60.20
13,	49.00	50.40	51.80	53.20	60.10	61.60	63.00

[1] Milligrams in 100 cubic centimeters broth.

Graphic Representation (1) of Table 10 (Proteolysis)

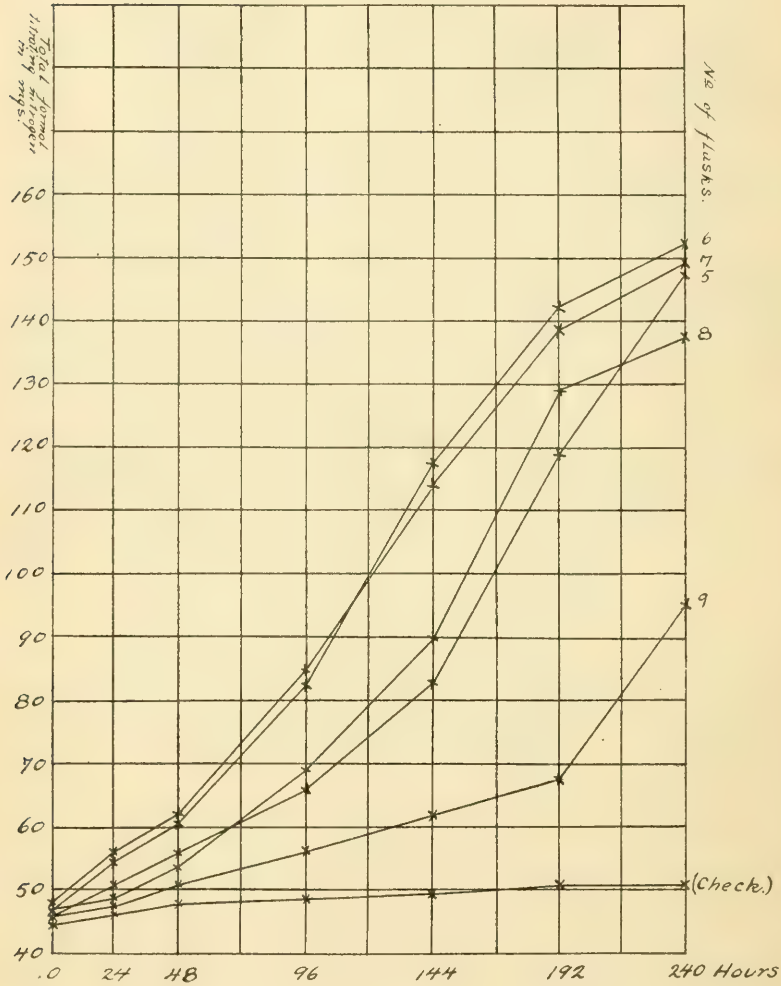

Table X. and Graph 1 indicate the proteolytic activity of *B. subtilis* during two hundred and forty hours' incubation at 37° C. From these results the following deductions may be made: —

1. The proteolysis occurred more or less in all the media including those used as controls. This may be due to hydrolysis brought about by the acid and alkali present, and also by the temperature of the incubator.

2. The greatest activity was manifested in the medium of which the original $P_{\dot{H}}$ was 5.42. In the same medium the rate of proteolysis increased most remarkably after its $P_{\dot{H}}$ was changed to 6.99 or higher.

3. The least proteolytic activity was observed in flask 9, at the end of two hundred and forty hours.

4. The formol titrating nitrogen increased slowly, especially in flasks 5 and 9, up to one hundred and forty-four hours, and then a rapid increase took place. This slow increase at the beginning may be due to the inhibitory reaction of the hydrogen ion concentrations upon the enzymes. After there had been a sufficient amount of protective substance produced the enzyme assumed greater activity.

5. It is probable that the enzyme which brought about the proteolysis in the investigation is tryptic-like in its nature, according to the present conception of the enzymatic classification. The greatest proteolysis took place toward the optimum hydrogen ion concentration, which is $P_{\dot{H}} = 8.076$ in this case. It has been shown that the optimum hydrogen ion concentration for trypsin varies according to the temperature, the materials used and other factors of environment. For instance, Palitzsch and Walbum[1] obtained the following results from their experiment, in which they employed 0.4 per cent. trypsin solution and 6 per cent. gelatin solution.

	Temperature (Degrees) C.			
	30.	**37.**	**45.**	**55.**
Optimum $\dot{H}$ ion concentration, .	$10^{-9\cdot9}$	$10^{-9\cdot7}$	$10^{-9\cdot1}$	$10^{-8\cdot0}$

These results indicate that as the temperature increases the optimum point changes toward the neutral point.

Again, Oppenheimer[2] quoted from Mesernitzky's[3] work on *B. prodigiosus,* and stated that the optimum hydrogen ion concentration for the proteolytic action of the organism is slightly less than that of trypsin (10^{-8}).

These references seem to confirm the author's deduction.

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[1] Biochem. Zeitschr., Bd. 47, Heft 1, S. 34.

[2] Oppenheimer, C. Die Fermente u. Ihre Wirkungen, 4 Auflage, Bd. II, S. 617.

[3] Mesernitzky, P. Biochem. Zeitschr., 29, 104, 1910.

Determination of Hydrogen Ion Concentration as Growth progressed.

For this purpose 20, of the 50 cubic centimeters of the medium which had been pipetted out from each flask, were used. The results will be given in terms of $P_{\dot{H}}$.

Table XI. — *Following the Change of Hydrogen Ion Concentration.*

Number of Flask.	Original.	24 Hours.	48 Hours.	96 Hours.	144 Hours.	192 Hours.	240 Hours.
Control,	5.62[1]	5.81	5.93	5.82	5.79	5.78	5.77
1,	0.86	0.85	0.85	0.82	0.81	0.81	0.80
2,	1.86	1.74	1.70	1.68	1.67	1.65	1.62
3,	2.62	2.82	2.75	2.72	2.70	2.60	2.65
4,	4.18	4.13	4.12	4.11	4.08	4.05	4.00
5,	4.82	5.05	5.06	5.48	6.17	7.21	7.89
6,	5.42	5.62	5.83	6.26	6.99	7.87	8.19
7,	6.42	6.66	6.72	6.78	7.48	8.13	8.16
8,	8.17	8.08	7.77	7.58	7.72	8.06	8.13
9,	9.43	9.20	9.00	8.70	8.56	8.01	8.01
10,	10.47	10.25	10.24	10.22	10.18	10.15	10.09
11,	11.22	11.11	11.33	11.29	11.28	11.19	11.22
12,	11.60	11.58	11.45	11.35	11.37	11.35	11.38
13,	12.80	12.95	12.95	12.92	12.90	12.87	12.91

[1] $P_{\dot{H}}$ or exponent of hydrogen ion concentration.

Graphic Representation (2)
of
Table 11
(Automatic adjustment of (H) in medium.)

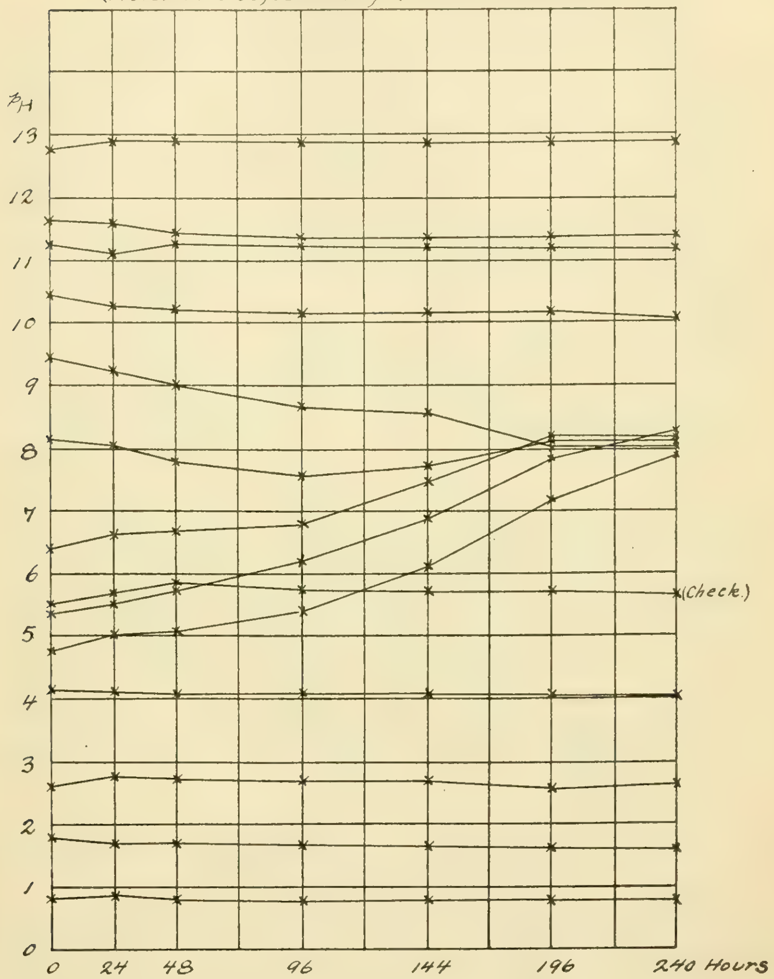

Table XI. and Graph 2 indicate the following P_{H} in the media:—

1. Alteration of P_{H} in the media occurred within the limit of $P_{\dot{H}}$ 4 to 10 in the course of growth; that is,

$P_{\dot{H}} = 4.82$ changed to $P_{\dot{H}} = 7.89$
$P_{\dot{H}} = 5.42$ changed to $P_{\dot{H}} = 8.19$
$P_{\dot{H}} = 6.42$ changed to $P_{\dot{H}} = 8.16$
$P_{\dot{H}} = 8.17$ changed to $P_{\dot{H}} = 8.13$
$P_{\dot{H}} = 9.43$ changed to $P_{\dot{H}} = 8.01$
average $P_{\dot{H}} = 8.076$.

On the other hand, in the media where no growth was observed $P_{\dot{H}}$ remained practically constant.

2. Minimum $P_{\dot{H}}$ for *B. subtilis* lies between 4 and 5.
3. Optimum $P_{\dot{H}}$ for *B. subtilis* lies between 7.5 and 8.5.
4. Maximum $P_{\dot{H}}$ for *B. subtilis* lies between 9 and 10.
5. The alteration of $P_{\dot{H}}$ in the media occurred in such a way that different $P_{\dot{H}}$'s were brought toward the optimum $P_{\dot{H}}$. This peculiar alteration of $P_{\dot{H}}$, or so-called "automatic adjustment," is very interesting because it occurred in each of four similar experiments which came under the author's observation. An explanation of this peculiar adjustment remains to be discussed. It was thought by the author that this phenomenon is due to the production of ammonia present as an end-product of proteolysis. This cannot be true, however, because $P_{\dot{H}}$ above the optimum decreased rather than increased; for instance, $P_{\dot{H}} = 9.43$ became $P_{\dot{H}} = 8.01$. Again, it cannot be due to the increased amount of amphoteric substance which has resulted from the growth, because $P_{\dot{H}} = 8.17$ changed only to $P_{\dot{H}} = 8.13$, while other $P_{\dot{H}}$'s were altered markedly, and also against theoretical expectation. It is pertinent to consider the presence of the so-called "protective substance" in enzymatic work in connection with this discussion. In enzymatic work it has been shown by Hudson and Paine[1] and others that cane sugar acts as a protective substance in the case of invertin, especially in the destruction of the enzyme by ethyl alcohol. Recently Chapman[2] demonstrated the relative action of propyl alcohol, methyl acetate and methyl-ethyl ketone upon the invertin, with and without sugar, bringing out strikingly the protective value of cane sugar. It may not be erroneous to consider that in this investigation a protective substance is present or produced in the medium, the action of which may be analogous to that of cane sugar in the case of invertin; that is, the hydrogen ion concentration in the medium is altered by some protective substances bringing it to the optimum concentration for proteolytic enzymatic activity.

Determination of Character of the Proteolysis, viz., Ereptic, Peptic and Tryptic in Nature.

In the media consisting of different hydrogen ion concentrations, namely $P_{\dot{H}} = 1$ to $P_{\dot{H}} = 13$, which have been described elsewhere, the character of the proteolysis was determined according to the following general principle:[3] if the proteolysis occurs in the media measuring $P_{\dot{H}} = 7$, then it is suggested that this is ereptic; greater than $P_{\dot{H}} = 7$, tryptic; and less than $P_{\dot{H}} = 7$, peptic in nature.

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[1] Jour. Amer. Chem. Soc., V. 32, 1910, 1353.

[2] Internat. Zeitschrift f. Physik.-Chem. Biologie, Bd. I, Heft 5 u. 6, S. 293.

[3] Julius Wohlgemuth. Grundriss der Fermentmethoden, 1913, 135, 182; C. Oppenheimer. Die Fermente u. Ihre Wirkungen, Bd. II, 1913, S. 617; Sven Palitzsch u. L. E. Walbum. Biochem. Zeitschr., Bd. 47, Heft 1, S. 1–35.

DETERMINATION OF THE ENDO- OR EXO-ENZYMATIC NATURE OF ENZYMES.

Does *B. subtilis* produce endo- or exo-enzyme? To determine this the following procedure was adopted: after *B. subtilis* was cultivated in 500 cubic centimeters of Medium IV. ($P_{\dot{H}} = 6.90$), at 37° C. for 120 hours, the contents were divided into two equal portions; namely, A and B. Portion A was filtered through a Chamberland porcelain filter[1] under aseptic conditions, and the filtrate, together with portion B (in the original condition), was placed in the incubator at 37° C. for forty-eight hours. At the end of this period the filtrate was carefully examined both macroscopically and microscopically, in order to verify sterility. The filtrate was then taken for inoculation. Three flasks were filled with 400 cubic centimeters Medium IV. ($P_{\dot{H}} = 6.90$). One of these was kept for control and marked "control;" the second one was marked "1," and inoculated with 1 cubic centimeter of the portion B; and the third was marked "2" and inoculated with 1 cubic centimeter of the filtrate A. These flasks were kept in the incubator and the determinations for $P_{\dot{H}}$ and formol titrating nitrogen were made. The results are indicated on Table XII. and represented in Graph 3.

TABLE XII. — *Determination of Character of Enzyme.*

	NUMBER OF FLASK.	Original.	24 Hours.	48 Hours.	96 Hours.	144 Hours.	192 Hours.	240 Hours.
$P_{\dot{H}}$	Control,	6.90	6.88	6.80	6.85	6.85	6.90	7.00
	1,	7.11	7.18	7.20	7.30	7.60	7.90	8.10
	2,	6.99	7.00	7.05	7.10	7.13	7.20	7.20
F. N.	Control,	46.00[2]	46.40	47.50	49.00	49.50	50.00	51.00
	1,	49.00	55.00	61.50	91.00	121.50	140.50	146.00
	2,	48.10	49.00	50.50	52.00	53.00	55.00	57.00

F. N. — formol titrating nitrogen.

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[1] Zak. Hofm. Beitr., 10, 287, 1907; Schmailowitsch, F. Zbl. Biochem., I, 467; de Waele, H. Zbl. Bakt., 50, 40, 1909.

[2] Milligrams in 100 cubic centimeter medium.

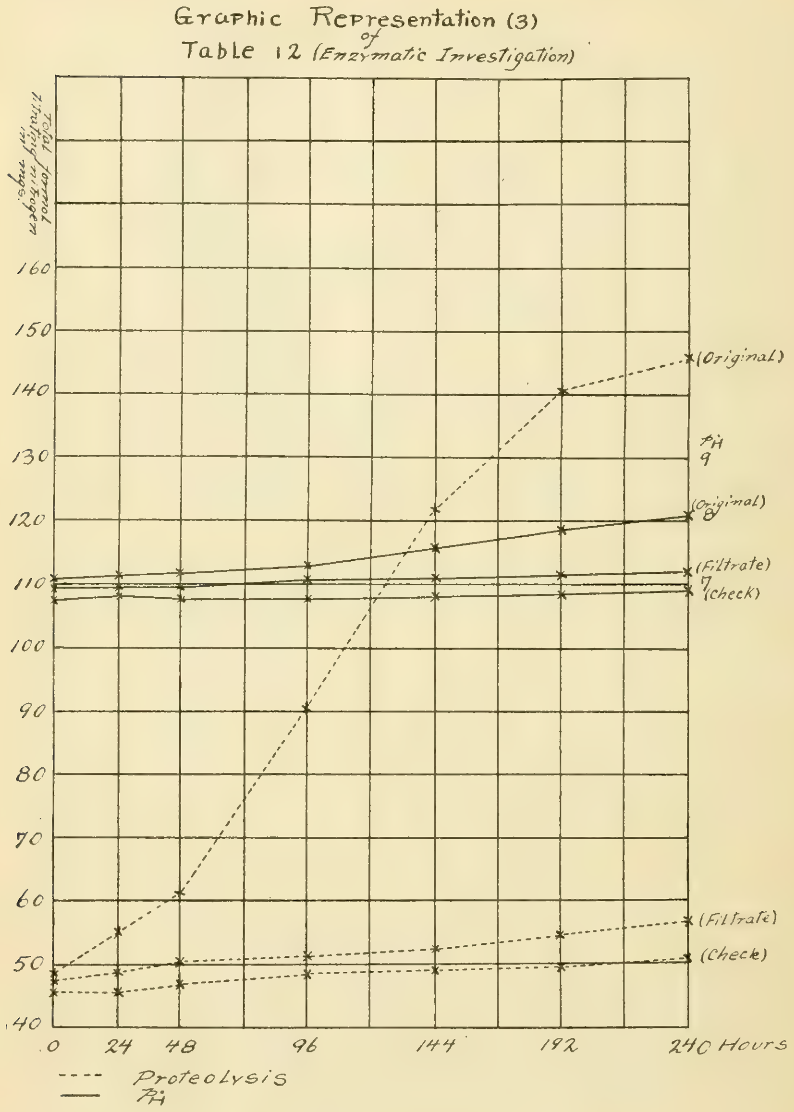

Table XII. and Graph 3 indicate the following: —

1. PḢ in flask 1 increased toward the optimum PḢ or, changed from PḢ=7.11 to PḢ=8.10, while PḢ in the control and flask 2 increased very slightly.

2. The amount of formol titrating nitrogen in flask 1 increased from 49 to 146 milligrams, while in the others the increase was very slight.

From these results it may be said that *B. subtilis* produces endo-enzyme and no exo-enzyme. The author may not, however, be justified in applying the term "enzyme" in this connection, because the proteolysis which took place in flask 1 might have been brought about by any one of the following agents: —

1. Enzyme.
2. Direct action of the living protoplasm.
3. Enzyme and the living protoplasm.

The distinction between these factors, in the light of present knowledge, is not easily made, although the matter has been investigated by some workers. For instance, Gotschlich[1] would distinguish between the action of enzyme and the living protoplasm as follows: "Fermentation is a direct function of the living protoplasm, and serves as its source of energy," while "enzyme action is not directly dependent on the living protoplasm, and does not serve the organism as a source of energy." In order to demonstrate these statements there are several methods; for example, the use of antiseptics which kill the causal organisms but do not measurably impair the enzyme. Kaufmann[2] has shown that very dilute enzymes are nearly as susceptible to antiseptics as are bacteria. Thus it may be understood that the distinction between these factors is not easily made. The author has taken the liberty to designate these causal substances in this investigation as enzymes, and has distinguished endo- and exo-enzymes according to the method employed.

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[1] Kolle u. Wassermann's Handbuch, V. 1, 104.

[2] Zeit. Physiol. Chem., 1903 (39), 434.

PART II.

PROTEOLYSIS OF STREPTOCOCCUS ERYSIPELATIS AND STREPTOCOCCUS LACTICUS COMPARED UNDER DIFFERENT HYDROGEN ION CONCENTRATION.

INTRODUCTION.

As intimated previously, the methods of proteolysis under different hydrogen ion concentrations as described, might furnish a means for assisting in differentiating closely related organisms. An application is here attempted with *Streptococcus erysipelatis* and *Streptococcus lacticus.* The significance of streptococci in market milk, and the indiscriminate practice of attributing many afflictions to them, have led to this choice of organisms, for it involves the so-called virulent and avirulent strains of streptococci. Heinemann[1] and others have demonstrated that *Streptococcus lacticus* is very closely related to *Streptococcus pyogenes,* not only morphologically and culturally, but also in pathogenicity.

GENERAL METHODS OF PROCEDURE.

ORGANISMS EMPLOYED IN THE INVESTIGATION.

(*a*) *Streptococcus Erysipelatis* (*Streptococcus* "*E* ").

Furnished by H. K. Mulford Company, Philadelphia. Virulent for rabbit, Guaranty No. 172.

(*b*) *Streptococcus Lacticus.*

Isolated by the author from starter at this institution and found to be avirulent for rabbit.

MEDIUM.

Composition: —

500 gms. chopped lean beef[2] 1 per cent. Witte's peptone 0.5 per cent. NaCl	per 1,000 c. c. of water.

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[1] Heinemann, P. G. Jour. Infect. Diseases, 4, No. 1, 89, Jan., 1907.

[2] Chopped lean beef, rather than Liebig's meat extract, was found to be favorable for this investigation.

First, 2,500 cubic centimeters double-strength bouillon of the above composition was prepared as follows: 2,500 grams chopped lean beef was placed in 2,500 cubic centimeters distilled water for twenty-four hours at 15° C. (this infusion was strained through two layers of cheesecloth); 50 grams Witte's peptone and 25 grams NaCl were mixed together in a smooth paste, with 500 cubic centimeters of the strained infusion. Care must be exercised to leave no unbroken globular masses of peptone. Add the peptone emulsion to the rest of the infusion and make up to the required volume. Autoclave fifteen minutes under 15 pounds' pressure. Adjust the reaction to very faint pink for phenolphthalein by the addition of n/1 NaOH;[1] then autoclave for forty-five minutes, and filter through Swedish filter paper. Control the volume. Place 200 cubic centimeters of the bouillon thus prepared into each of eleven Erlenmeyer flasks (500 cubic centimeters) and sterilize in the autoclave for thirty minutes. The remaining portion may be employed to estimate the hydrogen ion concentration as previously described; that is, at first an approximate reaction is determined by the colorimetric method,[2] then finally electrically.[3] The following table indicates the various amount of n/1 NaOH or n/1 HCl and distilled water (sterilized) to be added separately[4] to obtain the different hydrogen ion concentrations desired: —

TABLE I. — *Preparation of Media.*

	Desired $P_{\dot{H}}$	Found $P_{\dot{H}}$	Number of —					Total Volume.
			Cubic Centimeter 2X Broth.	Cubic Centimeter Inoculation.	Cubic Centimeter n/1 HCl.	Cubic Centimeter n/1 NaOH.	Cubic Centimeter H_2O.	
Set 1.	Control,	7.60	200.0	–	–	–	200.0	400.0
	5.5,[5]	4.79	199.0	1	8	–	192.0	400.0
	6.5,	6.35	199.0	1	4	–	196.0	400.0
	7.5,	7.65	199.0	1	–	–	200.0	400.0
	8.5,	8.76	199.0	1	–	4	196.0	400.0
	9.5,	9.55	199.0	1	–	8	192.0	400.0
Set 2.	5.5,[5]	4.80	199.0	1	8	–	192.0	400.0
	6.5,	6.45	199.0	1	4	–	196.0	400.0
	7.5,	7.62	199.0	1	–	–	200.0	400.0
	8.5,	8.85	199.0	1	–	4	196.0	400.0
	9.5,	9.63	199.0	1	–	8	192.0	400.0

Sets 1 and 2 were prepared at the same time.
$P_{\dot{H}}$ — exponent of hydrogen ion concentration, explained previously.
Inoculation was made with 1 cubic centimeter of forty-eight hour lactose broth culture.

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[1] This manipulation is found to be necessary in order to have the bouillon remain clear.

[2] It has been described previously on p. 161.

[3] It has been described previously on p. 145.

[4] It has been described previously on p. 163.

[5] This has been treated on p. 161.

After the hydrogen ion concentration has been adjusted the flasks are placed in an incubator at 37° C. for twenty-four hours, to establish their sterility as well as to maintain the medium at this temperature. After this period 1 cubic centimeter of a forty-eight-hour lactose broth culture of each, *Streptococcus erysipelatis* and *Streptococcus lacticus,* was used to inoculate Set 1 and Set 2, respectively. Observations of rate of growth, hydrogen ion concentration and proteolysis were made at the various intervals as indicated in tables.

RATE OF GROWTH.

It seemed essential to determine the rate of growth in connection with the other factors. This was done macroscopically, by taking a degree of turbidity[1] as an indicator. The results are recorded in Table 2.

TABLE 2. — *Rate of Growth.*

	NUMBER OF FLASK.	TIME IN HOURS.						
		6.	12.	18.	24.	48.	72.	120.
Set 1.	Control,	—	—	—	—	—	—	—
	5,	—	—	—	—	—	—	—
	6,	+	+	+	++	++	++	++
	7,	++	+++	+++	+++	+++	+++	+++
	8,	+	++	++	++	++	+++	+++
	9,	—	+	+	++	++	++	+++
Set 2.	5,	—	—	—	+	+	++	++
	6,	—	—	+	+	++	++	++
	7,	—	—	+	+	++	++	++
	8,	—	—	+	+	+	+	++
	9,	—	—	—	—	—	—	—

— none. + slight. ++ moderate. +++ abundant.
Set 1 — *Streptococcus erysipelatis.*
Set 2 — *Streptococcus lacticus.*

This table indicates that *Streptococcus erysipelatis* grows best in the medium of which the hydrogen ion concentration is 2.24×10^{-8} or optimum; the growth becomes slower as the hydrogen ion concentration decreases; an increase of the hydrogen ion concentration seems to have some deleterious influence upon the growth, viz., $(\dot{H})=1.59\times10^{-5}$ has lethal influence. On the other hand, *Streptococcus lacticus* grows very slowly in all the media except $(\dot{H})=2.35\times10^{-10}$. This is interesting to note because it suggests stimulation by preceding environmental conditions. *Streptococcus erysipelatis* has existed in the medium of an animal body of which the reaction of blood is approximately $P_{\dot{H}}=7.56$ or $(\dot{H})=2.75\times10^{-8}$;[1] on the other hand, *Streptococcus lacticus* existed previous to the isolation in the starter of which the reaction is about $P_{\dot{H}}=5$ or $(\dot{H})=1\times10^{-5\cdot2}$[2] Considering these facts with the results obtained, the correlation between the degree of growth in the medium of different hydrogen ion concentration and their previous surroundings is indicated.

---

[1] This has been described in the previous work.

RATE OF PROTEOLYSIS.[3]

TABLE 3. — *Proteolysis.*

	Number of Flask.	Time in Hours.							
		Original.	6.	12.	18.	24.	48.	72.	120.
Set 1.	Control,	40.10[4]	40.25	40.30	40.50	40.50	40.80	41.00	41.20
	5,	42.00	42.60	43.80	42.00	44.00	44.40	44.20	44.80
	6,	42.00	44.80	53.20	57.40	58.00	60.80	61.20	63.70
	7,	43.40	47.60	57.40	60.20	60.80	68.60	74.20	77.00
	8,	40.00	46.20	51.80	54.60	57.40	60.80	65.80	68.60
	9,	42.50	44.80	50.40	53.20	54.60	57.40	57.40	60.80
Set 2.	5,	43.40	43.40	44.80	44.80	43.40	44.80	44.80	44.90
	6,	39.20	42.00	43.40	43.40	46.20	47.00	49.10	55.00
	7,	42.00	42.40	43.40	47.60	49.00	50.20	51.60	53.50
	8,	40.60	41.00	40.60	43.40	46.20	47.20	49.10	49.80
	9,	40.60	42.00	42.50	43.50	43.40	44.80	43.40	44.80

Set 1 — *Streptococcus erysipelatis.*
Set 2 — *Streptococcus lacticus.*

Table 3 indicates the following: —

Set 1 (*Streptococcus erysipelatis*). — The greatest proteolysis occurred in flask 7, and practically no proteolysis in flask 5; at the end of six hours proteolysis appeared.

Set 2 (*Streptococcus lacticus*). — The greatest proteolytic activity was manifested in flask 6 and practically none in flask 9; it was not until the end of eighteen hours that slight proteolysis began to appear.

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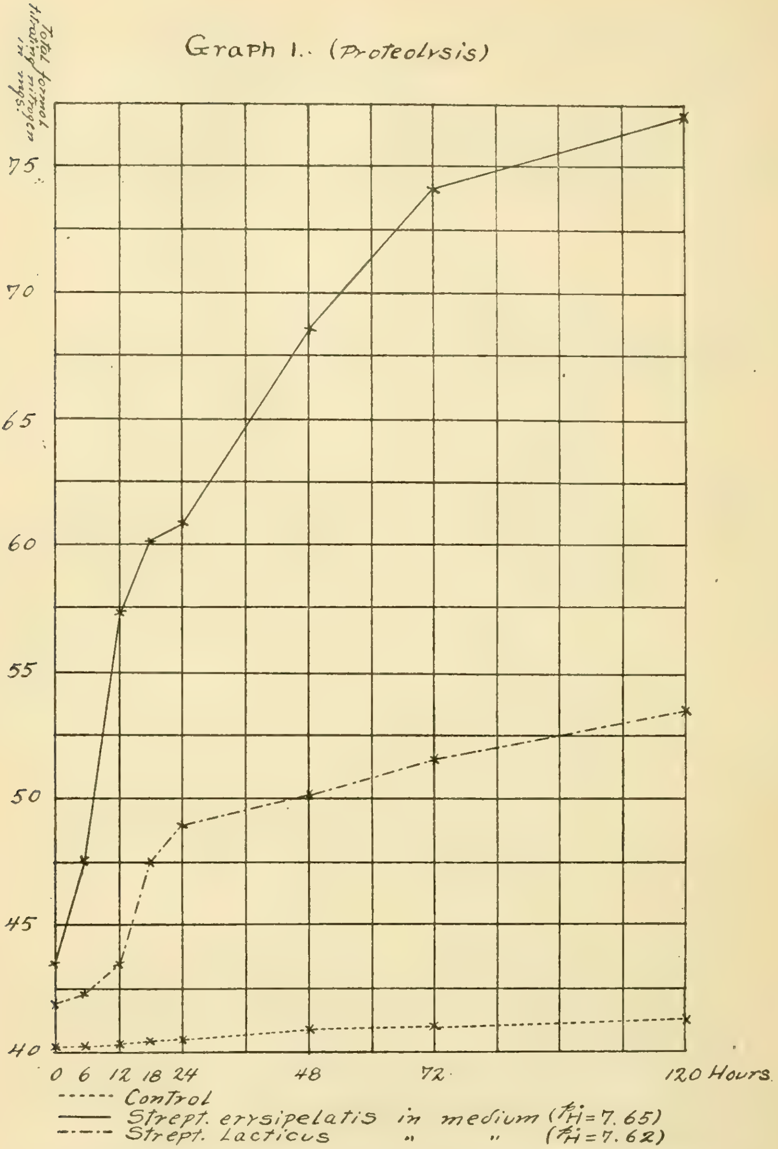
[1] Michaelis, L. Die Wasserstoffionenkonzentration, Berlin, 101, 1914.

[2] $(\dot{H})$ of starter from which the organism was isolated.

[3] The method for determination has been described previously.

[4] Milligrams per 100 cubic centimeters.


Graph 1.. (Proteolysis)

Graph 1 represents the proteolysis of *Streptococcus erysipelatis* and *Streptococcus lacticus* in the media of which the hydrogen ion concentration is $(\dot{H}) = 2.24 \times 10^{-8}$ and $(\dot{H}) = 2.40 \times 10^{-8}$, respectively. The results in these two media (the same within the limit of error) were especially considered instead of the optimum hydrogen ion concentration for proteolysis in the case of each organism. The reason for this is to be found in an effort to comply with the purpose of this investigation.

From these results the following deductions may be made: —

A difference in the degree and also the rate of proteolysis between *Streptococcus erysipelatis* and *Streptococcus lacticus* is shown.

Again, it seems to suggest a correlation between the proteolysis, also, and the preceding environmental factors as stated under "Rate of Growth." *Streptococcus erysipelatis* existing in the animal body rich in body proteins with only a slight amount of carbohydrate present and at 37° C., with *Streptococcus lacticus* existing in a medium of abundant carbohydrates as well as protein substances and at 20° C. or less, must be influenced by their former habitats.

According to this stimulation, generally recognized by physiologists, *Streptococcus erysipelatis* would naturally give rise to abundant proteolytic enzymes, while *Streptococcus lacticus* would produce enzymes acting on carbohydrate (lactose). Such a case seems to be indicated in the present work.

DETERMINATION OF HYDROGEN ION CONCENTRATION AS GROWTH PROGRESSED.[1]

TABLE 4. — *$P_{\dot{H}}$ in Media.*

	Number of Flask.	Time in Hours.							
		Original.	**6.**	**12.**	**18.**	**24.**	**48.**	**72.**	**120.**
Set 1.	Control, . .	7.60	7.65	7.63	7.68	7.66	7.60	7.65	7.80
	5, ...	4.79	4.85	4.80	4.89	4.88	4.75	4.80	4.90
	6, ...	6.35	6.43	6.65	6.78	6.90	7.00	7.20	7.40
	7, ...	7.65	7.70	7.80	7.85	7.80	7.75	7.70	7.65
	8, ...	8.76	8.50	8.30	8.20	7.90	7.80	7.85	7.60
	9, ...	9.55	9.30	9.20	9.05	8.80	8.75	8.60	8.20
Set 2.	5, ...	4.80	4.85	4.90	4.85	4.75	4.70	4.75	4.75
	6, ...	6.45	6.53	6.60	6.65	6.70	6.85	6.90	7.10
	7, ...	7.62	7.65	7.68	7.70	7.66	7.74	7.70	7.60
	8, ...	8.85	8.70	8.60	8.55	8.50	8.40	8.35	8.20
	9, ...	9.63	9.55	9.53	9.53	9.50	9.60	9.55	9.65

Set 1 — *Streptococcus erysipelatis.*
Set 2 — *Streptococcus lacticus.*

Table 5 indicates the occurrence of an adjustment (automatic adjustment)[2] of the hydrogen ion concentration in the media. Attention was called to this phenomenon and its probable explanation given in the previous work.[3]

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[1] This has been explained previously.

[2] See p. 172.

[3] See p. 174.

SUMMARY AND CONCLUSIONS.

Part I.

1. The determination of "true reaction" in such a bacteriologic culture medium as was used in the investigation can be made successfully by means of the hydrogen electrode.

2. Sörensen's formol titration method gives very satisfactory results in determining the rate of proteolysis.

3. Medium IV. seems very suitable for the determination of hydrogen ion concentration and proteolysis in the case of *B. subtilis.* In order to secure a fixed chemical and physical factor it is advisable to boil it for an hour or place it in an autoclave for thirty minutes or longer, under 15 pounds' pressure.

4. The desired hydrogen ion concentration in the medium is obtained by the aid of the colorimetric method, avoiding sterilization after the addition of acid or alkali.

5. $P_{\dot{H}} = 9.43$ seems to have an inhibitory action upon *B. subtilis*, while $P_{\dot{H}}$'s below 4.18 and above 9.43 have a germicidal effect.

6. The minimum, optimum and maximum $P_{\dot{H}}$ for *B. subtilis* are as follows: —

Minimum, between $P_{\dot{H}} = 4$ and $P_{\dot{H}} = 5$.
Optimum, between $P_{\dot{H}} = 7.5$ and $P_{\dot{H}} = 8.5$.
Maximum, between $P_{\dot{H}} = 9$ and $P_{\dot{H}} = 10$.

7. An alteration of the hydrogen ion concentration in the medium by *B. subtilis* occurred between $P_{\dot{H}} = 4.18$ and $P_{\dot{H}} = 9.43$.

8. *B. subtilis* produced a tryptic-like enzyme which is endo-cellular.

From the foregoing summary the relation between the hydrogen ion concentration in the medium and the proteolytic activity of *B. subtilis* may be concluded as follows: certain hydrogen ion concentrations measure the exact influence both inhibitory and prohibitory, and indicate the exact limits of the proteolytic activity of *B. subtilis.* Further, the hydrogen ion concentrations of the medium converged toward the optimum as proteolysis proceeded.

Part II.

1. *Streptococcus erysipelatis,* the virulent strain, multiplied much more rapidly in the broth than *Streptococcus lacticus,* the nonvirulent strain.

2. A difference both in degree and rate of proteolysis is evident; *Streptococcus erysipelatis* is much more active and vigorous than *Streptococcus lacticus.*

3. The optimum hydrogen ion concentration for proteolysis differs, as follows: —

$P_{\dot{H}} = 7.62$ or $(\dot{H}) = 2.40 \times 10^{-8}$ for *Streptococcus erysipelatis.*

$P_{\dot{H}} = 7.02$ or $(\dot{H}) = 9.55 \times 10^{-8}$ for *Streptococcus lacticus.*

4. Alteration of the hydrogen ion concentrations toward the optimum occurred during the course of proteolysis.

These results for *Streptococcus erysipelatis* and *Streptococcus lacticus* point to a very close relationship between the optimum hydrogen ion concentration for proteolysis (in the bouillon) and the hydrogen ion concentration of their natural environmental conditions (blood and milk, respectively).

So far as this investigation is concerned, the differentiation of *Streptococcus erysipelatis* and *Streptococcus lacticus*, virulent and avirulent streptococci, through their proteolytic activity in conjunction with certain hydrogen ion concentration in culture medium, seems to be promising, although further data are desired before its generalization may be realized.

In connection with this investigation, the author's gratitude is due to Prof. S. P. L. Sörensen, Prof. A. Klöcker, Dr. H. Jessen-Hansen and Dr. Sven Palitzsch, of the Carlsberg Laboratory, Copenhagen, Denmark; to Prof. A. Hopkins of Amherst College; to Prof. J. S. Chamberlain and Prof. F. H. H. van Suchtelen of this institution; especially to Prof. C. E. Marshall, under whom the work of this thesis has been concluded.

BULLETIN No. 168 MAY, 1916

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION.

REPORT OF CRANBERRY SUBSTATION FOR 1915.

By H. J. FRANKLIN.

This bulletin discusses fully the work carried on at the cranberry substation at East Wareham in 1915. It presents more or less definite conclusions in connection with the following lines of investigation: frost protection, effects of spraying with Bordeaux mixture and of treating the water of a June reflow with copper sulfate for the control of fungous diseases, factors affecting the amount of shrinkage of cranberries in storage and in transportation (with practical suggestions), the effects of resanding, the results of fertilizer experiments, and methods of destroying injurious insects. The results of several years' tests of resanding and of the use of commercial fertilizers, as shown by quantities and keeping qualities of the fruit obtained, are summarized. Much new information concerning the insect pests and their parasites is presented, and a new and comprehensive system of cranberry bog management is advanced for the consideration of Massachusetts growers.

Requests for bulletins should be addressed to the
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[1] On account of ill health not in administrative charge.

[2] In administrative charge.

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Approved by the State Board of Publication.

REPORT OF CRANBERRY SUBSTATION FOR 1915.

BY H. J. FRANKLIN.

The season's studies followed chiefly the lines of previous years, but more extensive storage experiments were conducted with the fruit than heretofore, and considerable attention was given to the possibility of growing selected varieties of the swamp blueberry (*Vaccinium corymbosum* L.) on bogs where cranberries do not pay, somewhat more than half an acre of land having been partially prepared to test the feasibility of this substitution.

It is hoped that Massachusetts cranberry growers will give special consideration to the new ideas suggested in the discussion of bog management. They are advanced, not as established principles, but as possibilities which, in the light of general experience and the results of several years of extensive investigation, appear to be promising.

Weather observations were carried on as in previous seasons, the readings of the maximum and minimum thermometers and the amounts of precipitation being telegraphed to the Boston office of the United States Weather Bureau during the periods of frost danger, and advice concerning temperature possibilities being given by telephone to individual growers on cold nights when asked for.

Experiments with tobacco shade cloth for frost protection were continued, with the general result that its use for this purpose appears less advisable than the 1914 tests seemed to indicate, the difficulties connected with its manipulation on the bog evidently being considerable. The cloth should be given further trial, however. There is as yet no other promising means of protection for many dry bogs, but the total acreage of such bogs is small. In the present opinion of the writer, a cheaper and more certainly effective means of protection may be had on most unprotected bogs by properly conserving and manipulating (by means of small pumping plants, the bog areas being more extensively divided by low dikes) the water of the winter flowage (see the more extended discussion of this idea on page 46).

FUNGOUS DISEASES.

These studies were carried on, as heretofore, in co-operation with the Bureau of Plant Industry of the United States Department of Agriculture, Dr. C. L. Shear having charge of the more technical part of the work.

Table 1 is a record of the season's experience with the spraying plots, experiments with which have been reported in previous years. Plots C and E were left without treatment as in 1914, and only one-half of plots B and D were sprayed this year. As in 1914, Bordeaux mixture (with resin fish-oil soap) was the only fungicide used, the final spraying with neutral copper acetate applied in former years being omitted. The different areas treated this year were sprayed as follows: plot A, three times, on June 28, July 24 and August 7; half of plot B, three times, on June 28, July 28 and August 9; half of plot D, three times, on June 29, July 19 and August 7; "1913," three times, on June 28, on July 15 and 24 (half of the plot treated on the former date and half on the latter) and on August 9; half of fertilizer plot 15, three times, on June 28, July 18 and August 7. No fertilizer was applied to any of these plots, except the half of fertilizer plot 15, this season. All the plots were picked with scoops as usual. Where two checks were taken they were laid out on opposite sides of the plot, and their areas and fruit production were combined in making up the record given in Table 1.

TABLE 1. — *Results of Spraying for Fungous Diseases.*

PLOT.	Whether sprayed in 1915 or not.	Area of Plot (Square Rods).	Variety.	Date picked.	Quantity of Fruit obtained (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Quantity of Fruit placed in Storage Tests (Bushels).[1]	Period of Storage Test.	Method of Examination for Rot Percentage.[2]	Per Cent. of Loss by Rot in Storage Test.
A (middle portion),	Sprayed.	8	Late Howe.	Oct. 13	2.75	.344	2.75	Oct. 13 to Jan. 8	Five-sample.	11.25
A (side strips),	Sprayed.	8	Late Howe.	Oct. 13	1.75	.219	1.75	Oct. 13 to Jan. 7	Five-sample.	7.48
A (2 checks),	Not sprayed.	13	Late Howe.	Oct. 13	11.81	.908	5.00	Oct. 13 to Jan. 8	Five-sample.	13.89
B (part sprayed in 1915),	Sprayed.	7 1/16	McFarlin.	Oct. 13	2.33	.330	2.33	Oct. 13 to Jan. 6	Five-sample.	6.29
B (part not sprayed in 1915),	Not sprayed.	7 1/16	McFarlin.	Oct. 13	3.07	.435	3.00	Oct. 13 to Jan. 7	Five-sample.	19.05
B (1 check),	Not sprayed.	13 2/3	McFarlin.	Oct. 13	10.83	.793	4.00	Oct. 13 to Jan. 7	Five-sample.	12.60
C,	Not sprayed.	16	Late Howe.	Oct. 14	1.60	.100	1.50	Oct. 14 to Jan. 5	Five-sample.	11.29
C (2 checks),	Not sprayed.	16	Late Howe.	Oct. 14	3.70	.231	3.00	Oct. 14 to Jan. 7	Five-sample.	8.90
D (part sprayed in 1915),	Sprayed.	8	Early Black.	Sept. 22	3.40	.425	4.00	Sept. 22 to Jan. 3	Five-sample.	17.06
D (part not sprayed in 1915),	Not sprayed.	8	Early Black.	Sept. 22	5.00	.625	4.00	Sept. 22 to Jan. 5	Five-sample.	33.41
D (1 check),	Not sprayed.	12	Early Black.	Sept. 22	13.75	1.146	4.00	Sept. 22 to Jan. 5	Five-sample.	28.63
E,	Not sprayed.	16	Early Black.	Sept. 22	7.33	.458	–	– –	– –	–
E (1 check),	Not sprayed.	12	Early Black.	Sept. 22	6.83	.569	–	– –	– –	–
"1913,"	Sprayed.	9	Late Howe.	Oct. 14	2.40	.267	–	– –	– –	–
"1913" (2 checks),	Not sprayed.	6	Late Howe.	Oct. 14	1.67	.278	–	– –	– –	–
Sprayed half of fertilizer plot 15,	Sprayed.	4	Early Black.	Sept. 16	2.50	.625	2.33	Sept. 16 to Jan. 6	Five-sample.	24.22
Other half of plot 15,	Not sprayed.	4	Early Black.	Sept. 16	3.33	.833	3.33	Sept. 16 to Jan. 6	Five-sample.	27.33

[1] All this fruit was stored in bushel crates.

[2] See the general discussion of this season's storage tests (p. 6).

It will be seen that the results with these plots were entirely in line with the experience of former years, the quantity of fruit obtained from the sprayed areas being in every case distinctly less than that produced by the untreated checks. Moreover, the plots which had been treated for several years, and on which the spraying was suspended in 1915, also yielded distinctly less fruit than their checks, thus showing a marked persistence of the results of the injury caused by the treatment. The results of the storage tests show the same benefit from the spraying, as regards its effect on the keeping quality of the berries, as that obtained in previous seasons. It should be observed, however, that in every case tested, the berries from the areas on which the treatment of previous years was suspended showed poorer keeping quality than did those from their checks which had never been treated. This seems to show that the good results obtained by spraying do not persist from one year to another.

The possibility of controlling fungous diseases by putting copper sulfate in the flowage was tested again this season, a solution of the chemical being used in the June reflow on flooding sections 23 and 27 (of station bog) at the rate of 1 part to 50,000 parts of water (1 pound in 6,250 gallons). The treatment was applied June 17, after these sections had been completely flooded for fifteen hours, and the water was then held twenty-nine hours longer. An even distribution of the chemical was obtained by constantly dragging it around in a sack in the water as it dissolved. The blossom buds were well developed, but they did not show any injury from the treatment. Both the treated and untreated flooding sections were picked with scoops on September 17, the former showing no advantage in the quantity of fruit obtained. In storage tests, however, the berries from the treated sections showed smaller percentages of rot than did those from the other sections, though the advantage apparently obtained was not great enough to be especially gratifying. These results are similar to those obtained in 1914. They are shown more in detail in the following table: —

TABLE 2. — *Effect of Treatment with Copper Sulfate in June Reflow.*

Flooding Section.	Variety.	Area of Section (Square Rods).	Quantity of Fruit picked (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Period of Storage Test.	Quantity of Fruit stored (Bushels).	Loss by Rot in Storage Test (Per Cent.).	Method of Examination for Rot Percentage.
21	Early Black.	21.30	9.50	.446	Sept. 17 to Jan. 3	4	23.75	Five-sample.
23[1]	Early Black.	12.80	3.35	.262	Sept. 17 to Jan. 3	3	21.74	Five-sample.
25	Early Black.	11.60	3.43	.296	Sept. 17 to Jan. 3	3	35.44	Five-sample.
27[1]	Early Black.	10.66	5.23	.491	Sept. 17 to Jan. 5	4	19.57	Five-sample.
29	Early Black.	10.61	7.85	.740	Sept. 17 to Jan. 7	4	24.78	Five-sample.

[1] Treated.

The special tests with Bordeaux mixture, made up with varying proportions of lime and copper sulfate, both with and without resin fish-oil soap, to determine the causes for the root injury observed, as described in previous reports, in connection with the spraying experiments have been continued and extended, but have not yet advanced far enough to give definite results.

The writer visited the New Jersey cranberry growing section in July, and examined bogs there which had been sprayed regularly with Bordeaux mixture for several years. The last treatment of the season was being applied at the time. No indication of any such injury as that caused in the spraying tests conducted by the writer at East Wareham was seen. The reason for the difference in the results of this treatment on Cape Cod and in New Jersey is not yet evident. It may be connected in some way with the fact that on most New Jersey bogs sand is not used for a surface mulch as in Massachusetts. Results seem to amply justify spraying with Bordeaux mixture to control cranberry fungous diseases in New Jersey, but this treatment is distinctly on probation on Cape Cod bogs.

The disease spoken of as "Wisconsin false-blossom" in the 1914 report of the substation was discovered this season on Metallic Bell and Bennett Jumbo vines on a bog in Wareham, the infestation being very serious with both varieties. These vines came originally from City Point and Mather, Wis., and had been planted on the Wareham bog about four years. Early in July this disease was reported by Miss Elizabeth C. White as being present on Bennett Jumbo vines on a bog belonging to her father near New Lisbon, N. J., these vines having come from Wisconsin in May, 1908. She stated that from 5 to 10 per cent. of the blossoms on these vines were affected, and that the disease had also been found, to some extent, on "Centennial vines in the same and adjoining bogs." Some time afterward the writer visited these bogs and succeeded in finding a few vines which showed plainly the effects of the disease, though the area planted to the Bennett Jumbo variety had then been burned over. It will be seen that evidence tending to prove the disease infectious is accumulating. Special studies to determine this point have been started. Vines of the Berlin Bell variety, which came originally from Wisconsin, growing on bogs in Bourne and Plymouth, were examined carefully late in June, but no trace of this disease was found upon them.

The new disease, called the "blossom-end rot" in previous reports, appeared to be distinctly less prevalent than usual this season, the fruit of the Late Howe variety, as a rule, keeping unusually well. Dr. Shear is continuing his technical investigation of the fungus which causes this disease.

Storage Tests.

As a part of the fungous disease investigation, extensive storage tests were conducted during the fall and early winter to determine the effects of some of the factors affecting the keeping quality of cranberries. The descriptions of all of these tests that gave results of any considerable interest or value are arranged in groups, according to the purposes of the tests, in the following list.

(*a*) *To determine the General Relationship of Ventilation (Relative Humidity) to the Rate of Decay.* — The five distinct series of tests under this head were as follows: —

1. Eighty-four bushels of Early Black berries (4 bushels from each of the 21 fertilizer plots) were stored in bushel picking crates (with slatted bottom and sides) right after they were picked, just as they came from the bog (*i.e.*, without being run through the separator or otherwise cleaned). Table 3 shows the results of this series of tests in detail. Plots 1 and 2 were picked on September 14; 3 to 20, inclusive, on September 16; and 21, on September 17.

For the first month these boxes were stacked in the basement of the station screen-house without regard to order, but during the rest of the storage period the four from each plot were placed in a stack by themselves.

Cup samples were taken for making the examinations by which the counts, summaries of which are given in Table 3, were obtained. The cup used was the inspectors' cup of the New England Cranberry Sales Company, and the examinations were made, under the writer's supervision, by the "screeners" who had been employed at the station during the fall, New England Cranberry Sales Company's inspectors' hand-graders being used to facilitate the work. The dates of these examinations ranged from January 3 to January 7, inclusive. As indicated in Table 3, entirely and partly decayed berries were counted together in determining the percentages of rot.

What is called in this report the "five-sample" method was used in making these examinations. In this method, five samples from each box were examined: one sample, Te (1) and Te (2), being taken from the top or surface berries at each end of the box; one sample, Me (1) and Me (2), being taken from the berries halfway between the top and the bottom of the box at each end; and one sample, Mm, being taken from the very center of the box.

TABLE 3. — *Relationship of Ventilation (Relative Humidity) to Rate of Decay. — Results of First Series of Storage Tests.*

PLOT.	TE (1).			TE (2).			ME (1).			ME (2).			MM.		
	Total Number of Berries in the Samples of the Four Boxes.	Total Number of Rotten and Partly Rotten Berries in the Four Samples.	Percentage of Rotten and Partly Rotten Berries.	Total Number of Berries in the Samples of the Four Boxes.	Total Number of Rotten and Partly Rotten Berries in the Four Samples.	Percentage of Rotten and Partly Rotten Berries.	Total Number of Berries in the Samples of the Four Boxes.	Total Number of Rotten and Partly Rotten Berries in the Four Samples.	Percentage of Rotten and Partly Rotten Berries.	Total Number of Berries in the Samples of the Four Boxes.	Total Number of Rotten and Partly Rotten Berries in the Four Samples.	Percentage of Rotten and Partly Rotten Berries.	Total Number of Berries in the Samples of the Four Boxes.	Total Number of Rotten and Partly Rotten Berries in the Four Samples.	Percentage of Rotten and Partly Rotten Berries.
1,	493	101	20.49	509	120	23.58	469	106	22.60	486	134	27.57	514	189	36.77
2,	448	117	26.12	474	116	24.47	432	156	36.11	461	134	29.07	489	161	32.92
3,	475	102	21.47	465	94	20.22	462	96	20.56	480	105	21.88	512	130	25.39
4,	469	116	24.73	437	107	24.49	460	126	27.34	476	125	26.26	479	126	26.30
5,	466	146	31.33	467	137	29.34	445	124	27.87	463	139	30.02	462	166	35.93
6,	475	106	22.32	460	120	26.09	482	133	27.59	467	109	23.34	513	168	32.75
7,	492	148	30.08	464	116	25.00	477	135	28.30	460	127	27.61	496	145	29.23
8,	466	111	23.82	455	119	26.15	461	109	23.64	456	123	26.97	488	136	27.87
9,	527	85	16.13	518	106	20.46	492	123	25.00	508	108	21.26	541	150	27.73
10,	505	121	23.96	498	92	18.47	496	100	20.16	481	116	24.12	476	126	26.47
11,	454	177	38.99	475	176	37.05	449	158	35.19	467	181	38.76	481	173	35.97
12,	446	130	29.15	468	107	22.86	441	133	30.16	443	123	27.77	475	160	33.68
13,	457	64	14.00	462	77	16.67	448	60	13.39	442	70	15.84	470	81	17.23
14,	425	95	22.35	460	121	26.30	452	126	27.88	435	122	28.05	464	142	30.60
15,	456	112	24.56	449	113	25.17	438	116	26.48	456	115	25.22	462	162	35.06
16,	450	94	20.89	450	100	22.22	482	99	20.54	447	84	18.57	472	123	26.06
17,	491	84	17.11	477	83	17.40	497	103	20.72	476	78	16.39	497	99	19.92
18,	465	104	22.37	478	95	19.87	456	111	24.34	445	118	26.52	479	116	24.22
19,	474	82	17.30	468	88	18.80	463	102	22.03	488	115	23.57	499	125	25.05
20,	462	116	25.11	471	129	27.39	466	137	29.40	476	138	28.99	519	180	34.67
21,	470	106	22.55	461	111	24.08	471	113	23.99	475	134	28.21	505	153	30.31
Averages,	470	110⅓	23.47	470	111	23.62	464	117½	25.32	466	119	25.54	490	143	29.24

As will be seen by comparing the percentages in the line of averages in the above table, the amount of decay in these boxes was least among the top berries and greatest among those at the center of the box; and the berries at the ends of the box, halfway between the top and bottom, showed more rot than did the surface berries, but less than did those at the center, it being self-evident that the distribution of the decay was governed largely by the ventilation to which the berries in the different parts of the box were subject. The averages of the table show further that, at the end of the test, the berries at the center of the box were considerably smaller than those in the other parts (it taking a larger number to fill the cup used in sampling), while those taken from halfway between the top and the bottom of the ends of the box were slightly larger than were the surface berries. In the opinion of the writer this variation in the size of the berries from the different parts of the box was an exhibition of the varying resultant of the combined action of the three factors which appear to be most important as causes of shrinkage in cranberry storage, namely: —

(1) Advanced Decay: Berries in this condition are thrown away in separating and screening. A marked softening and frequently a shriveling accompany the complete disintegration of the fruit tissue. Rotten berries, under even moderate pressure, will take up less room in proportion to their number than will sound ones. The variation in the percentage of such berries in the different parts of the box would, therefore, necessarily have a bearing on the relative number of berries in the samples.

(2) Incipient Decay: This is not usually superficially apparent. The hardly discernible softening and shriveling which accompanies the slight disintegration of the fruit tissue in the early stages of decay appears to be a very potent cause of shrinkage both in the size of the individual berries and in the quantity of fruit in the mass. The shriveling of berries of the Early Black variety which has been generally supposed to be caused by loss of water appears to be due to this disintegration of incipient decay. As there is an optimum temperature for the development of the fungi which cause decay, there seems to be, in connection with this kind of shrinkage, a suggestion that it may be possible to develop a heating test by which inspectors can determine the relative keeping qualities of cranberries before they are shipped.

(3) Loss of Water: It is as yet impossible to say how great the shrinkage in the size of the berries due to water loss is, but it appears to be much less than that caused by either the incipient or advanced decay described above.

It would seem that in these tests the berries halfway between the top and bottom, at the ends of the boxes, suffered less shrinkage in size because, on the one hand, they were not subject (their ventilation being less) to as much loss of water as were the surface berries, and, on the other hand, they did not develop as much decay as did those at the center, their gain from reduction in loss of water more than offsetting their greater shrinkage from increased decay as compared with the surface berries. With the berries at the center of the box, however, the increase in incipient and advanced decay, in comparison with that of the other berries, was evidently sufficient to cause a shrinkage which the reduction in the loss of water could only partly offset.

2. Two lots, one consisting of 64 bushels (16 stacks of 4 boxes each) of Early Black berries, and the other of 36 bushels (9 stacks of 4 boxes each) of Late Howe berries, were stored as were the berries in the first series of tests. The Early Black berries were picked on different dates between the 13th and 22d of September, and the Late Howe between the 12th and 22d of October. The berries of both lots were examined during the first week in January in the same way as were those in the first series. The averages of the totals of the four counts obtained in the examination of the samples of the four boxes of each stack are given in the following table: —

TABLE 4. — *Relationship of Ventilation (Relative Humidity) to Rate of Decay. — Results of Second Series of Storage Tests.*

LOT.	Number of Bushels in Lot.	Part of Box examined.	Total Number of Berries in the Samples of the Four Boxes.	Total Number of Rotten and Partly Rotten Berries in the Four Samples.	Percentage of Rotten and Partly Rotten Berries.
Early Black, . .	64 (16 stacks of 4 boxes each),	Te (1).	477¾	124	25.95
		Te (2).	496½	134¾	27.14
		Me (1).	484¾	139¾	28.83
		Me (2).	483⅓	138	28.55
		Mm.	506	163½	32.31
Late Howe, . .	36 (9 stacks of 4 boxes each),	Te (1).	387½	48¼	12.45
		Te (2).	392⅔	46⅓	11.80
		Me (1).	380	52½	13.82
		Me (2).	385	47	12.21
		Mm.	389⅔	64	16.42

For an explanation of the lettering in the table indicating the different parts of the box examined, see the description of the "five-sample" method given above in the discussion of the first series of tests. As the figures of the table show, the results of this series of tests were entirely similar to those of the first series.

3. Thirty-nine boxes (bushel picking crates with slatted bottoms and sides), some with Early Black and some with Late Howe berries. This fruit was stored like that in the first two series of tests. It was picked on

different dates in September and October, and was examined during the first week in January by what is called in this report the "nine-sample" method. In this method nine samples from each box were examined, one sample, Te (1) and Te (2), being taken from the top or surface berries at each end of the box; one sample, Tm, from the surface berries at the middle of the box; one sample, Me (1) and Me (2), from the berries halfway between the top and the bottom of the box at each end; one sample, Mm, from the very center of the box; one sample, Be (1) and Be (2), from the very bottom of the box at each end; and one sample, Bm, from the bottom of the box at the middle. The totals of the counts of each of these samples from all of the thirty-nine boxes in this series of tests are given in the following table: —

TABLE 5. — *Relationship of Ventilation (Relative Humidity) to Rate of Decay. — Results of Third Series of Storage Tests.*

PART OF BOX EXAMINED.	Total Number of Berries in 39 Samples.	Total Number of Rotten and Partly Rotten Berries in 39 Samples.	Percentage of Rotten and Partly Rotten Berries.
Te (1),	4,352	496	11.40
Te (2),	4,358	529	12.14
Tm,	4,346	663	15.26
Me (1),	4,272	582	13.62
Me (2),	4,333	602	13.89
Mm,	4,465	910	20.38
Be (1),	4,383	520	11.86
Be (2),	4,306	551	12.80
Bm,	4,523	760	16.80

The results of this series of tests, as shown by the figures in the table, confirm those of the first two series. The berries at the bottom of the box developed less decay than those halfway between the top and bottom, and those at the middle of the box (at the top and the bottom as well as at the center) rotted more than those at the ends, this giving additional evidence that the berries most subject to ventilation decay least rapidly.

4. Two lots, one consisting of 3 bushels of Late Howe berries stored in three 1-bushel boxes, and the other of 3 bushels of berries of the same variety, picked at the same time and in the same place as those of the first lot, divided up equally among nine boxes of the same size and construction as those used for storing the first lot, their sides being slatted and their bottoms solid, all being new. This series of tests was begun on October 29, and the berries were examined on January 10; the "nine-sample" method of examination, described in the discussion of the third

series, being used with the three boxes of the first lot, and each of those of the second lot being sampled six times, one sample being taken from among the surface berries at each end of the box; one from the surface berries at the middle of the box; one from the bottom berries at each end of the box; and one from the bottom berries at the middle of the box. By this examination the percentage of decay among the berries of the three full boxes was determined to be 10.31 per cent., while it was found to be only 7.63 per cent. in the nine one-third full boxes, the berries which were subject to the better ventilation thus showing the smaller proportion of rot.

As in all the other storage tests discussed in this report, the work of examining this fruit was done by "screeners" under the writer's supervision, sampling cups and hand-graders being used as described in the discussion of the first series of tests.

5. Ninety-six tin 1-quart cans filled with Late Howe cranberries during the last week in October were stored with the covers on tight, but not sealed. These berries were examined on the 4th and 5th of January, the contents of each can being divided into five separate samples which were taken in order from the top to the bottom of the can. Each of the first four samples filled the sampling cup; but the fifth, consisting of what was left at the bottom of the can, varied somewhat and only partly filled the cup. The totals of the counts of each of these samples from all of the ninety-six cans in this series of tests are given in the following table: —

TABLE 6. — *Relationship of Ventilation (Relative Humidity) to Rate of Decay. — Results of Fifth Series of Storage Tests.*

SAMPLE.	Total Number of Berries in 96 Samples.	Total Number of Rotten and Partly Rotten Berries in 96 Samples.	Percentage of Rotten and Partly Rotten Berries.
1, ...	8,784	1,751	19.93
2, ...	8,800	2,159	24.53
3, ...	8,650	2,466	28.51
4, ...	8,626	2,755	31.91
5, ...	5,595	1,875	33.51

The table shows there was a rapid and constant increase in the percentage of decayed berries from the top to the bottom in these cans. As their only ventilation took place around the close-fitting covers, it seems certain that the top berries were better ventilated than those lower down in the cans. The results of this series of tests, therefore, evidently strongly confirm those obtained in the four series previously discussed.

(*b*) *To determine the Relative Water Loss of Cranberries in Storage in*

Boxes of Different Construction and in Different Periods of the Storage Season. — The two series of tests, in this connection, were as follows: —

1. Two lots, each consisting of 6 bushels of Late Howe berries, all picked in the same location on October 22 and all stored on October 23, one lot being placed in new bushel boxes with solid bottoms and solid sides, and the other in new boxes of the same dimensions with solid bottoms and slatted sides. Tables 7 and 8 show how the tests with these two lots of fruit were arranged and carried out. The six boxes of each lot were placed in a single stack, No. 1 being the top box of the stack and No. 6 the bottom one. These berries were weighed in their boxes on October 24, when the tests were begun, on December 18, on January 3, and when the tests ended, on January 10.

TABLE 7. — *Water Loss of Late Howe Cranberries in Boxes with Solid Bottoms and Sides in Different Periods of the Storage Season.*

Box Number.	Weight (Gross) on October 24 (Ounces).	Weight (Gross) on December 18 (Ounces).	Loss in Weight between October 24 and December 18 (Ounces).	Average Daily Loss between October 24 and December 18 (Ounces).	Weight (Gross) on January 3 (Ounces).	Loss in Weight between December 18 and January 3 (Ounces).	Average Daily Loss between December 18 and January 3 (Ounces).	Weight (Gross) on January 10 (Ounces).	Loss in Weight between January 3 and January 10 (Ounces).	Average Daily Loss between January 3 and January 10 (Ounces).	Weight of Empty Box on January 10 (Ounces).	Net Weight of Berries on October 24 (Ounces).[1]	Net Weight of Berries on January 10 (Ounces).[1]	Total Loss in Weight between October 24 and January 10 (Ounces).[1]	Percentage of Weight Shrinkage (due to Loss of Water) between October 24 and January 10.
1, ...	758	738	20	.3636	734	4	.2500	732	2	.2857	146	612	586	26	4.25
2, ...	746	731	15	.2727	728	3	.1875	726	2	.2857	140	606	586	20	3.30
3, ...	753	738	15	.2727	734	4	.2500	733	1	.1429	138	615	595	20	3.25
4, ...	755	739	16	.2909	736	3	.1875	735	1	.1429	144	611	591	20	3.27
5, ...	740	720	20	.3636	717	3	.1875	716	1	.1429	135	605	581	24	3.97
6, ...	744	723	21	.3818	720	3	.1875	718	2	.2857	143	601	575	26	4.33
Averages, ...	749⅓	731½	17⅚	.3242	728	3⅓	.2083	726⅔	1½	.2143	141	608⅓	585⅔	22⅔	3.73

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[1] The change in the weight of the boxes themselves during the storage was thought to be so small that it was neglected in making these computations. Several empty new boxes, entirely similar to those used in these tests, were weighed on October 24 and again on January 10 and were found to have lost 2 ounces each. It seems probable, however, that, when filled with berries, these boxes absorbed enough of the moisture given off by the fruit to largely offset their own loss of water. Unfortunately, this absorption, as being a possible factor of some importance, was not foreseen in planning these tests.

TABLE 8. — *Water Loss of Late Howe Cranberries in Boxes with Solid Bottoms and Slatted Sides in Different Periods of the Storage Season.*

BOX NUMBER.	Weight (Gross) on October 24 (Ounces).	Weight (Gross) on December 18 (Ounces).	Loss in Weight between October 24 and December 18 (Ounces).	Average Daily Loss between October 24 and December 18 (Ounces).	Weight (Gross) on January 3 (Ounces).	Loss in Weight between December 18 and January 3 (Ounces).	Average Daily Loss between December 18 and January 3 (Ounces).	Weight (Gross) on January 10 (Ounces).	Loss in Weight between January 3 and January 10 (Ounces).	Average Daily Loss between January 3 and January 10 (Ounces).	Weight of Empty Box on January 10 (Ounces).	Net Weight of Berries on October 24 (Ounces).[1]	Net Weight of Berries on January 10 (Ounces).[1]	Total Loss in Weight between October 24 and January 10 (Ounces).[1]	Percentage of Weight Shrinkage (due to Loss of Water) between October 24 and January 10.
1, ...	771	749	22	.4000	745	4	.2500	743	2	.2857	142	629	601	28	4.45
2, ...	759	740	19	.3455	737	3	.1875	735	2	.2857	144	615	591	24	3.90
3, ...	746	724	22	.4000	720	4	.2500	719	1	.1429	143	603	576	27	4.48
4, ...	736	717	19	.3455	713	4	.2500	712	1	.1429	142	594	570	24	4.04
5, ...	757	737	20	.3636	734	3	.1875	732	2	.2857	145	612	587	25	4.08
6, ...	758	734	24	.4364	729	5	.3125	728	1	.1429	144	614	584	30	4.89
Averages, . . .	754½	733½	21	.3818	729⅔	3⅚	.2396	728	1½	.2143	143⅓	611	585	26⅓	4.31

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[1] The change in the weight of the boxes themselves was not considered (see explanation in connection with Table 7, above).

The figures given in Tables 7 and 8 show that there was a much greater daily loss of water in the first part of the storage period (from October 24 to December 18) than in the last part (from December 18 to January 10). This probably was to be expected on account of the higher temperature of the first part of the storage period. The great variation in the average daily loss between January 3 and January 10, shown in the tables, was due to the fact that differences of less than an ounce were not clearly indicated by the scales used in weighing. It will be seen that the berries in the boxes with slatted sides lost, on the average, about 15 per cent. more water than did those with solid sides.

2. Three bushels of Late Howe berries, picked on October 22 in the same location as the two lots in the previous series of water-loss tests, were stored on October 23 in old and well-seasoned bushel boxes with bottoms and sides slatted. These boxes were stacked one on another, and, as in all the other storage experiments with boxes described in this report, an empty box was put underneath the stack. This test was conducted as an extension of the previous series. The berries were weighed in the boxes twice, at the beginning and at the end of the storage. The results of the test are shown in detail in the following table: —

TABLE 9. — *Water Loss of Late Howe Cranberries in Boxes with Bottoms and Sides Slatted.*

BOX NUMBER.	Weight (Gross) on October 24 (Ounces).	Weight (Gross) on January 10 (Ounces).	Weight of Empty Box on January 10 (Ounces).	Net Weight of Berries on October 24 (Ounces).[1]	Net Weight of Berries on January 10 (Ounces).	Loss in Weight between October 24 and January 10 (Ounces).	Percentage of Weight Shrinkage, due to Loss of Water, between October 24 and January 10.
1,	771	739	137	634	602	32	5.05
2,	691	661	111	580	550	30	5.17
3,	655	624	145	510	479	31	6.08
Averages,	706	675	131	575	544	31	5.43

[1] The change in the weight of the boxes themselves was not considered.

A comparison of the figures in this table with those of Tables 7 and 8 shows that the berries in these boxes lost on the average about 45 per cent. more water than those in the solid boxes and about 26 per cent. more than those in boxes with solid bottoms and slatted sides. The average amount of decay in the solid boxes was found to be 9.26 per cent., while it was only 8.19 per cent. in the boxes with sides and bottoms slatted, there being, therefore, about 13 per cent. more rot in the former boxes than in the latter. This does not show a very marked advantage, as regards their effect on keeping quality, for the slatted boxes. It should be remembered, however, that the keeping quality of the berries used in these tests was exceptionally good. With berries of poorer keeping quality, the slatted boxes would naturally show a greater advantage.

As the figures in Tables 7, 8 and 9 show, the berries in the bottom box of each stack lost more water than did those in any of the other boxes, those in the top box as a rule coming second in this respect. The free circulation of air under the stacks, allowed by the presence of the empty box, was presumably responsible for the increased loss of the bottom box.

(*c*) *To determine the Effect of the Loss of Water as a Factor in Quantity Shrinkage.* — Only one series of tests was conducted in this connection, as follows: —

Early Black berries picked on September 11 were screened and packed in barrels on the 15th. They were then stored until October 11, when they were screened again and examined for size, counts of the number necessary to fill the inspectors' cup of the New England Cranberry Sales Company being taken. Some of this fruit was then placed in two new bushel picking boxes, with solid bottoms and slatted sides, and stored until January 19, when it was run through a separator, screened, and then examined again, as before, for size. These two boxes of berries were weighed five times, on the following dates: October 11, October 24, December 18, January 3 and January 10. The experience with this fruit is shown in detail in Tables 10, 11 and 12.

TABLE 10. — *Relative Water Loss of Early Black Cranberries, in Boxes with Solid Bottoms and Slatted Sides, in Different Periods of the Storage Season.*

BOX NUMBER.	Weight (Gross) on October 11 (Ounces).	Weight (Gross) on October 24 (Ounces).	Loss in Weight between October 11 and October 24 (Ounces).	Average Daily Loss between October 11 and October 24 (Ounces).	Weight (Gross) on December 18 (Ounces).	Loss in Weight between October 24 and December 18 (Ounces).	Average Daily Loss between October 24 and December 18 (Ounces).	Weight (Gross) on January 3 (Ounces).	Loss in Weight between December 18 and January 3 (Ounces).	Average Daily Loss between December 18 and January 3 (Ounces).	Weight (Gross) on January 10 (Ounces).	Loss in Weight between January 3 and January 10 (Ounces).	Average Daily Loss between January 3 and January 10 (Ounces).
1, ...	737	728	9	.6923	708½	19½	.3545	704½	4	.25	703	1½	.2143
2, ...	733	724	9	.6923	705	19	.3455	701	4	.25	699	2	.2857
Averages, .	735	726	9	.6923	706¾	19¼	.3500	702¾	4	.25	701	1¾	.2500

The table shows that the average daily water loss of these berries was about two and three-fourths times as great during the first period (October 11 to October 24) as it was during the last two periods (December 18 to January 10), while it was intermediate in amount in the second period

(October 24 to December 18). This strongly confirms the results obtained in the water-loss tests with Late Howe berries, showing, in the opinion of the writer, the effect of seasonal variation in temperature on water loss. It should be stated here, however, that no records of the humidity of the storage room were kept at any time in connection with any of the tests discussed in this report.

TABLE 11. — *Total Water Loss of Early Black Cranberries, in Boxes with Solid Bottoms and Slatted Sides, between October 24 and January 10.*

BOX NUMBER.	Weight (Gross) on October 24 (Ounces).	Weight (Gross) on January 10 (Ounces).	Weight of Empty Box on January 10 (Ounces).	Net Weight of Berries on October 24 (Ounces).[1]	Net Weight of Berries on January 10 (Ounces).	Loss in Weight between October 24 and January 10 (Ounces).	Percentage of Weight Shrinkage, due to Loss of Water, between October 24 and January 10.
1, ...	728	703	144	584	559	25	4.281
2, ...	724	699	139	585	560	25	4.274
Averages, . .	726	701	141½	584½	559½	25	4.277

As will be seen by a comparison of the figures in Table 8 with those in Table 11, the Late Howe berries averaged to lose approximately the same amount of water between October 24 and January 10 as did the Early Black fruit stored in the same way.

TABLE 12. — *Comparison of Weight Shrinkage (Water Loss) and Quantity Shrinkage.*

BOX NUMBER.	Net Weight of Berries on October 11 (Ounces).	Net Weight of Berries on January 10 (Ounces).	Loss in Weight between October 11 and January 10 (Ounces).	Percentage of Weight Shrinkage, due to Loss of Water, between October 11 and January 10.	Average Number of Berries in 7 Cup Samples (Screened) on October 11.	Average Number of Berries in 9 Cup Samples (Screened) on January 19.	Percentage of Quantity Shrinkage as shown by Comparison of Counts of Cup Samples of October 11 and January 19.
1, ...	593	559	34	5.734	109 3/7	115 2/3[2]	5.395
2, ...	594	560	34	5.724	111 2/7	115 2/3[2]	3.788
Averages, . .	593½	559½	34	5.729	110 5/14	115 2/3	4.590

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[1] The change in the weight of the boxes themselves was not considered.

[2] As the berries of the two boxes had become mixed in the process of screening, one set of cup samples answered for both.

A comparison of the percentages given in the table shows that the shrinkage in quantity from October 11 to January 19 averaged to be about 20 per cent. less than that in weight from October 11 to January 10. As is indicated by the word "screened," none of the berries in the cup samples showed decay. If the disintegration due to incipient decay was a large factor, as it probably was, in causing the quantity shrinkage, the loss of water in cranberry storage does not appear to cause anything like a corresponding loss in quantity of fruit.

(*d*) *To determine the Period in the Cranberry Storage Season in which the Greatest Development of Decay occurs.* — Only one series of tests was carried out for this purpose, as follows: —

Two lots of Late Howe berries, of 4 bushels each, picked in the same location on October 12, were stored in the same way in the same kind of boxes on October 26. One lot was run through a Hayden separator and screened just before it was stored, while the other was stored as it came from the bog, without any cleaning aside from the removal of such loose vines as could be readily taken out by hand. These eight boxes of fruit were examined by means of cup samples on January 8, 12¾ per cent. of rotten or partly rotten berries being found in the lot that was not cleaned before it was stored, while only 8¾ per cent. was found in the lot that was screened. If the tendency of these berries to decay was doubled by the process of cleaning, as, in the light of the results of tests described elsewhere in this report, seems very probable, it may be properly estimated that, if the cleaned lot of fruit had not been injured at all by the cleaning, its normally developed decay in these tests would not have been over 4⅜ per cent. If, then, 4⅜ per cent. may be fairly regarded as representing the normal amount of storage decay that developed among these berries between October 26 and January 8, as compared with 12¾ per cent., the total amount of rot found among the berries that were not cleaned previous to storage, it appears that over 8 per cent. of these berries, picked on October 12, were already partly or wholly rotten two weeks later. There was probably some rot among this fruit when it came from the bog, but, if this is neglected, it may be concluded that nearly twice as much rot developed in the period between the 12th and 26th of October as in that between the 26th of October and the 8th of January. It would appear from this that the most rapid development of decay takes place in the very first part of the storage season. Different lots of fruit infected with different diseases, however, probably would vary considerably in this respect.

(*e*) *To determine the Effect of an Admixture of "Vines" on the Development of Decay among Cranberries in Storage.* — No specially planned tests were carried out for this purpose, but the examination of the berries stored in boxes showed that, as a rule, in each stack those boxes which seemed to have the largest admixture of leaves also had the largest percentage of rotten berries. The writer does not consider, however, that the evidence at hand justifies a definite conclusion in regard to this, his observations in this connection being presented here merely as an indication that the generally accepted opinion among cranberry men, that berries keep better with vines among them, is possibly not correct. Vines without leaves would probably aid in the ventilation of stored berries and so help in retarding the development of rot. There is no evidence, on the other hand, to show that leaves might not have an entirely opposite effect, and, unfortunately, most of the vines that get mixed with the fruit in picking are well supplied with them. Tests to definitely determine this matter in the near future are planned.

(*f*) *To determine whether an Admixture of Decayed Berries usually promotes the Development of Rot in Cranberry Storage.* — The following single series of tests was conducted in this connection: —

Two dozen tin 1-quart cans were filled with Late Howe berries, taken carefully by hand from boxes of fruit that had not been run through a separator, on October 23, and were stored with their covers on tight but not sealed. In twelve of these cans all the berries were apparently entirely sound when stored, while in each of the other twelve, 10 entirely rotten berries were mixed with the good ones. When this fruit was examined on January 4, slightly less decay was found in the latter cans than in the former, there being no evidence to show that contact with the rotten berries had promoted the development of decay at all. Berries infected with different diseases, however, might have shown different results.

(*g*) *To determine the Relationship of the Degree of Ripeness of Cranberries when picked to their Keeping Quality.* — Two bushels of Early Black cranberries, picked on October 23, were placed in storage at once without any cleaning, being at that time very dark colored but apparently in good condition. This fruit was examined on January 10, and was then found to contain a larger percentage of rotten and partly rotten berries than any other lot tested, the other Early Black berries having been picked on different dates between the 10th and 23d of September and having been stored as they came from the bog. The experience with this fruit agrees with the results of similar tests carried out in previous seasons, in showing that there is a stage of ripeness beyond which the keeping quality of Early Black berries greatly deteriorates. It seems safe to say that berries of this variety should, if the winter flowage has been let off early the spring before, all be picked by the 15th of September, and should never under any circumstances be left on a bog later than the 25th of that month.

A lot of Late Howe berries, picked in a previous season on the 13th of November, developed less decay in storage than did any of the other untreated berries tested that year. In this year's tests the berries of this variety which were picked latest kept best. It seems probable, from these results and from other experience, that Late Howe berries, to be their best, should never be picked before the end of the first week in October.

(*h*) *To determine the Extent of the Injury to the Keeping Quality of Cranberries caused in the Process of "Separating."* — Five series of tests were conducted for this purpose, as follows: —

1. Three lots, each consisting of twelve 1-quart cans of Late Howe berries, none of which showed any decay when they were put in the cans, immediately after they had been run through a Hayden separator, on the 27th of October. The first lot was taken carefully by hand from among the berries in the separator barrels, the second lot in the same way from among those in the first separator box (the "good" box), and the third lot from those in the "second" box. When this fruit was taken out of storage on January 4, 21.28 per cent. of the berries in the first lot, 26.39 per cent. of those in the second lot, and 34.5 per cent. of those in the third lot were found to be partly or wholly rotten, the berries from the first separator box thus showing an increase of 24 per cent. and those from the second box an increase of about 62 per cent. in their tendency to rot as compared with that of the berries taken from the separator barrels. Unfortunately, no record was kept as to the part of the barrels (top, middle or bottom) from which the first lot of berries was taken.

2. This series was conducted as a check on the previous one, and was carried out in the same way in every respect, the berries being run through the separator and put in the cans on the 28th of October and being taken out of storage on the 5th of January. In this series 17.06 per cent. of the berries in the first lot were found to be entirely or partly rotten, as compared with 26.23 per cent. in the second lot and 34.27 per cent. in the third. The berries from the first separator box thus showed an increase of about 54 per cent. and those from the second box an increase of about 100 per cent. in their tendency to rot, as compared with those from the separator barrels. In the opinion of the writer the berries of the first lot, in this case, were taken from the top fruit of the separator barrels, though no record in regard to this was kept.

3. Two lots of Early Black fruit were stored in 1-quart cans on the 18th of January, none of the berries showing any rot at the time. The twelve cans of berries in the first lot were not run through a separator, but were taken carefully by hand from four boxes of uncleaned fruit, three cans being taken from the middle portion of each box, one from the top, one from the center and one from the bottom. The second lot, consisting of twenty cans of berries from the same four boxes from which those of the first lot were taken, was taken from separator barrels filled one-third full when this fruit was run through a Hayden machine. When these berries were examined one month later (February 18), an average of 17.14 per cent. of those in the first lot was found to be wholly or partly rotten, as compared with an average of 37.14 per cent. in the second lot, the tendency to rot, among the berries run through the separator, thus appearing to be about 117 per cent. greater than that of those taken directly from the uncleaned fruit. It is doubtful, however, if this figure fully represents the injury done in separating in this case, for the keeping quality of the berries in the first lot was probably poorer at the start than the average of that of the fruit in the four boxes from which the berries of both lots came, as clearly appears from the results of the third series of storage experiments discussed in this report (shown in Table 5).

4. Two lots, each consisting of six 1-quart cans of Late Howe berries, none of which showed any decay, were placed in storage on the 18th of January. The berries of both lots came originally from the same source. Those of the first lot, having been run through a Hayden separator only once, were taken from the first separator box (the "good" box). Those of the second lot, having been run through the separator once, were then taken from the first box and put through the machine a second time and caught in a box held close up to the spout of the separator in place of the separator barrels. This fruit was examined February 18, 12 per cent. of the berries in the first lot being found to be wholly or partly rotten, as compared with 23.44 per cent. of those in the second lot. It thus appears that the second machining of the second lot of berries caused an increase of about 95 per cent. in their tendency to decay.

5. Enough boxes of Late Howe berries from the same source were run through a Hayden separator on January 19 to fill both of the separator barrels. Nine tin 1-quart cans were filled with berries from the top of each of these barrels and placed in storage. Two-thirds of the fruit left in the barrels were then dipped out carefully, and nine more cans were filled with berries from the bottom portion of each barrel and stored for comparison with the other eighteen. None of the berries put into any of these cans showed any rot when they were placed in storage. They were taken out of storage and examined on February 19, the results obtained being shown in detail in the following table: —

TABLE 13. — *Injury to Keeping Quality of Cranberries caused by their Drop in Barrels.*

PART OF SEPARATOR BARREL FROM WHICH THE BERRIES WERE TAKEN.	Barrel.	Number of Cans.	Total Number of Berries in the Cans.	Number of Rotten and Partly Rotten Berries found on February 19.	Percentage of Berries found to be Rotten or Partly Rotten on February 19.	Averages of Percentages of Rotten and Partly Rotten Berries.
Top,	1	9	4,108	350	8.52	8.81
	2	9	4,351	396	9.10	
Bottom,	1	9	4,200	565	13.45	13.78
	2	9	4,128	583	14.12	

As will be seen by the above table, the rot development among the berries from the bottom part of the separator barrels, as compared with that in the fruit from the top part, showed that the injury due to the drop in the barrel had increased the tendency to rot about 56 per cent.

(*i*) *To determine the General Rate of Temperature Changes among Barreled and Crated Cranberries.* — The two following tests were conducted in this connection: —

1. Some Late Howe berries were heated in picking boxes in a warm room and packed in a barrel as if for shipment. A dough thermometer was inserted in a hole bored in the center of each head of the barrel, its bulb reaching in 9 inches among the berries; and another was placed in a hole in the bilge, its bulb reaching to the very center of the fruit. The temperature of the barreled berries at 5.15 P.M., February 15, was shown by these thermometers to range from 65 to 67 degrees Fahr. The barrel, with the thermometers in place, was then put at once in the basement of the station screen-house, the temperature of the basement at the time, as shown by a Green minimum thermometer placed near the barrel, being 34 degrees Fahr. During the following twenty-four hours, the basement temperature ranged between 31 and 34 degrees. The thermometers in the barrel, at 5.15 P.M., February 16, showed an average temperature of 51 degrees among the berries, their temperature having fallen about 15 degrees in the twenty-four hours. Between 5.15 P.M., February 16, and 5.15 P.M., February 17, the basement temperature ranged between 33 and 35½ degrees, and at the latter time the temperature of the barreled berries was found to average 42 degrees, it having dropped 9 degrees during the second period of twenty-four hours. Between 5.15 P.M., February 17, and 11.15 A.M., February 18, the basement temperature ranged from 32 to 36 degrees, and at the latter time the average temperature of the barreled berries was 38¾ degrees, it having dropped only 3¼ degrees in the last eighteen hours (or at the rate of 4⅓ degrees in twenty-four hours). At 5.15 P.M., February 18, the temperature of both the basement and the berries was 38 degrees. As will be seen, it took practically three days for the temperature of this barrel of berries to come down to that of the basement, there being an initial difference of about 32 degrees between them. Presumably, a considerably longer period would have been required to equalize these temperatures if that of the basement had not risen toward the end of the test.

When the length of time required to bring the temperature of this single barrel down to that of the basement is considered, it seems that the temperature changes of carload lots of barreled berries must be very slow.

2. A shipping crate of Late Howe cranberries was handled in the same way as the barrel of fruit in the previous test, except that a glass chemical thermometer, instead of a dough thermometer, was inserted into each compartment of the covered crate in such a way as to take the temperature of the berries at its very center. The temperatures were taken when those of the barrel test were. The average initial temperature of the berries in this crate was about 69 degrees Fahr. and it took it about forty hours to come down to that of the basement.

Practical Conclusions based on the Results of the Storage Tests.

Much of the experience gained in these experiments was of such a nature that it cannot be given in detail in this report, but it is considered freely, in connection with the results of the tests that have been described, in formulating the conclusions that follow: —

1. While ventilation is a very important factor in retarding the development of rot, it is doubtful if, all things considered, it would pay cranberry growers to go to any considerable expense in making special arrangements to provide for it in connection with the storage of their fruit previous to shipment, except, perhaps, in storage-house construction. As a rule, berries of poor keeping quality are shipped as soon as possible after they are picked, and it is only with such fruit that the maximum benefit to be gained by superior arrangements for ventilation would be realized. Some precautions, however, which do not call for much expenditure of either time or money, can apparently be taken with much advantage. Among these, the thorough airing of the storage house on cool, dry days, and the allowance of as much space in the storage of the fruit as circumstances permit, may probably be properly mentioned.

2. Special attention to the keeping down of temperatures appears to promise fully as great advantages, as far as storage previous to shipment is concerned, as can be obtained from special arrangements for ventilation.

3. Storage house construction, in its relations to temperature and humidity, is urgently calling for careful scientific study.

4. Methods of preparing the fruit for shipment are not receiving the attention they deserve. The following suggestions in this connection are here advanced for consideration: —

(*a*) The injury to the keeping quality of cranberries, caused in the process of their preparation for shipment by the methods at present generally followed, is enormous, and would be endured by hardly any other kind of fruit. Special harm appears to be done by the bouncing of the berries in the separators and by their drop into the barrels in separating and screening. It ought not to be difficult to devise simple means for greatly reducing this barrel injury, and separators of the general type of the White machine promise, in the opinion of the writer, to damage the fruit much less than those which employ the bouncing principle. Unfortunately, separators that make use of the snapping principle (White machine) are likely to be comparatively expensive, and, at the same time, have a relatively small capacity; these disadvantages, under present marketing conditions, making the use of such machines almost prohibitive, except with large growers. If community packing houses were established, however, such machines could probably be used extensively with no little advantage.

(*b*) No berries that are to be branded should ever be run more than once through a separator employing the bouncing principle.

(*c*) At present, cranberries are usually shipped in barrels, and the writer is informed that most dealers prefer to handle this fruit in such containers. If the maintenance of the fruit in good condition is a matter of first importance, however, great disadvantages are obviously connected with the use of the barrel. The pressure of the top fruit on that at the bottom in so large a package must do injury, and the squeezing which the berries undergo in the process of packing and the almost complete lack of ventilation in fruit packed so tightly in such quantity are certainly highly detrimental. In this connection it is here suggested that a thorough testing of the possibilities connected with the use of ventilated crates in shipping this fruit might produce valuable results. The use of such crates would not only help in preserving the condition of the berries while in transit, but would also insure, to a certain extent, a proper storage for them while they were in the hands of the retailer, ventilation being, as has already been shown, one of the more important factors in good cranberry storage. A desirable trade in cranberries shipped in crated strawberry baskets might perhaps be developed.[1]

(*d*) It may be found advisable to ship crated cranberries in the uncleaned condition (before they have been run through a separator) to the trade in the more distant parts of the country, for the fruit would be in a far more acceptable condition in such sections if it were prepared for market at central distributing points in the territory where it was to be consumed.[2]

(*e*) The slow rate of temperature changes in the barreled fruit suggests that berries might be moderately cooled, both before storage and before shipment, to advantage. The writer knows of no tests conducted in this connection, however.

Resanding.

The season's experience with the five sanding plots, results with which have been discussed in previous annual reports, are shown in detail in Table 14. The areas used as checks on these plots are measured off anew each year on the general bog surface immediately adjoining the plots, and, for this reason, as is shown in Table 15, they vary considerably in size from year to year. All the Early Black plots and their checks were picked this season on September 18, and the Late Howe plot with its checks on October 12, all the picking being done with scoops.

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[1] This suggestion is contributed by certain growers connected with the J. J. Beaton Growers Agency of Wareham, Mass.

[2] Suggested by Mr. J. J. Beaton, Wareham, Mass.

TABLE 14. — *Sanding Plots in 1915. — Effect of Resanding on Quantity and Keeping Quality of Cranberries.*

PLOTS AND CHECKS.	Variety.	Area of Plot (Square Rods).	When resanded.	Quantity of Fruit picked (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Number of Bushels in Storage Tests.	Date examined to determine Percentage of Rotten Berries.	Method of Examination.	Percentage of Berries found Partly or Wholly Rotten in Storage Test.
V, ...	Early Black.	9	Not since November, 1909.	12.875	1.43	4	Jan. 15	Nine-sample.	29.32
V (check 1), ...	Early Black.	9	Spring of 1912 and fall of 1914.	7.250	.81	4	Jan. 15	Nine-sample.	37.04
V (check 2), ...	Early Black.	9	Spring of 1912 and fall of 1914.	6.857	.76	4	Jan. 15	Nine-sample.	22.19
O, ...	Early Black.	9	Not since November, 1909.	8.125	.90	4	Jan. 15	Nine-sample.	19.95
O (check 1), ...	Early Black.	9	Fall of 1911 and fall of 1914.	8.500	.94	4	Jan. 14	Nine-sample.	22.58
O (check 2), ...	Early Black.	9	Fall of 1911 and fall of 1914.	4.670	.52	4	Jan. 15	Nine-sample.	25.01
N, ...	Early Black.	9	Yearly in the fall, 1911 to 1914, inclusive.	6.000	.67	4	Jan. 6	Five-sample.	19.21
N (check 1), ...	Early Black.	9	Fall of 1911 and fall of 1914.	6.500	.72	4	Jan. 6	Five-sample.	17.70
N (check 2), ...	Early Black.	18	Fall of 1911 and fall of 1914.	8.916	.50	-	-	- -	-
R, ...	Early Black.	9	Yearly in the fall, 1911 to 1914, inclusive.	8.110	.90	4	Jan. 8	Nine-sample.	20.86
R (check), ...	Early Black.	6	Fall of 1911 and fall of 1914.	3.900	.65	4	Jan. 8	Nine-sample.	17.25
T, ...	Late Howe.	9	Yearly in the fall, 1911 to 1914, inclusive.	11.500	1.28	4	Jan. 6	Five-sample.	13.53
T (check 1), ...	Late Howe.	9	Fall of 1911 and fall of 1914.	9.330	1.03	4	Jan. 6	Five-sample.	13.94
T (check 2), ...	Late Howe.	6	Fall of 1911 and fall of 1914.	6.330	1.06	4	Jan. 6	Five-sample.	13.37

Summary of Table 14.

	Area of Plots (Square Rods).	When resanded.	Quantity of Fruit picked (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Number of Bushels in Storage Tests.	Date examined to determine Percentage of Rotten Berries.	Percentage of Berries found Partly or Wholly Rotten in Storage Tests.
Plots O and V,	18	Not since November, 1909.	21.000	1.17	8	Jan. 15	24.635
Checks O and V,	36	Twice since 1909.	27.277	.76	16	Jan. 14, 15	26.705
Plots N, R and T,	27	Yearly in the fall, 1911 to 1914, inclusive.	25.610	.95	12	Jan. 6, 8	17.870
Checks N, R and T,	48	Twice since 1909.	34.976	.73	16	Jan. 6, 8	15.565

The amounts of fruit gathered from these plots and their checks each year, from 1912 to 1915, inclusive, and their averages, are given in the following table: —

TABLE 15. — *Effect of Resanding on Fruit Production.*

PLOTS AND CHECKS.	Variety.	Area (Square Rods).	When resanded.	QUANTITIES OF FRUIT PER SQUARE ROD (BUSHELS).				
				1912.	1913.	1914.	1915.	Average for the Four Years.
V,	Early Black.	9	Not since 1909.	.444	2.019	1.111	1.430	1.250
V (checks),	Early Black.	13½ to 21[1]	Spring of 1912 and fall of 1914.	.310	2.259	.856	.785	1.052
O,	Early Black.	9	Not since 1909.	.278	1.389	.889	.900	.864
O (checks),	Early Black.	18 to 24	Fall of 1911 and fall of 1914.	.258	1.917	.674	.730	.895
N,	Early Black.	9	Yearly in the fall, 1911 to 1914, inclusive.	Not started.	2.222	.800	.670	1.231
N (checks),	Early Black.	12 to 27	Fall of 1911 and fall of 1914.	-	2.358	.687	.610	1.218
R,	Early Black.	9	Yearly in the fall, 1911 to 1914, inclusive.	Not started.	1.889	1.111	.900	1.300
R (checks),	Early Black.	6 to 12	Fall of 1911 and fall of 1914.	-	1.944	1.125	.650	1.240
T,	Late Howe.	9	Yearly in the fall, 1911 to 1914, inclusive.	Not started.	2.278	1.259	1.280	1.606
T (checks),	Late Howe.	15 to 24	Fall of 1911 and fall of 1914.	-	2.424	1.213	1.045	1.561

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[1] There were two or three checks on each of these plots each year, except that plot R was given only one in 1915. These figures show the range in the total area of the checks added together in the various years. Whenever two checks were used they were laid out on opposite sides of the plot.

As will be seen by the figures given in Table 15, these plots have shown no very definite effect on the quantity of fruit produced, resulting from resanding or the lack thereof. In the opinion of the writer the advantages gained by resanding are of such a general nature — a certain amount of frost protection and help in the control of the tip worm and girdler being the most evident — that they are not definitely determinable by means of plot experiments.

Fertilizers.

The experiments with the fertilizer plots on the station bog, spoken of in previous reports, were continued. Table 16 presents a résumé of the experience with these plots from 1911, the year in which they were started, up to the present time. Unfortunately, no storage tests were conducted in 1911.

TABLE 16. — *Effect of Fertilizers on Quantity and Keeping Quality of Cranberries.*

PLOT.	Fertilizer used.	QUANTITIES OF FRUIT PRODUCED, 1911 TO 1915, INCLUSIVE (BUSHELS).						PERCENTAGES OF LOSS IN STORAGE TESTS, 1912 TO 1915, INCLUSIVE.				
		1911.	**1912.**	**1913.**	**1914.**	**1915.**	Total for the Five Years.	**1912.**	**1913.**	**1914.**	**1915.**	Average of the Four Years.
1,	0	10.0	1.875	15.833	9.000	5.833	42.542	34.38	37.26	27.45	26.26	31.34
2,	N	12.0	3.250	16.500	9.500	6.167	47.417	29.69	36.77	31.37	29.69	31.88
3,	P	11.0	2.000	15.667	8.800	5.500	42.967	27.81	33.00	20.59	22.20	25.90
4,	K	11.0	1.750	17.000	8.000	5.500	43.250	29.69	34.00	24.51	25.85	28.51
5,	0	13.0	1.750	19.333	6.500	7.600	48.183	29.70	39.22	26.96	32.13	32.00
6,	NP	16.0	3.143	19.167	6.667	7.750	52.727	23.44	38.24	34.00	26.53	30.55
7,	NK	14.5	3.875	18.833	7.667	8.000	52.875	21.88	30.88	31.37	28.09	28.05
8,	PK	14.5	2.750	17.750	8.667	8.167	51.834	18.75	35.29	23.53	25.71	25.82
9,	0	14.0	2.333	17.667	6.500	4.917	45.417	16.80	27.45	29.41	22.12	23.94
10,	NPK	14.0	4.000	20.000	8.667	7.333	54.000	18.75	35.30	33.00	22.51	27.39
11,	NPKL	16.0	3.500	17.750	8.167	6.333	51.750	16.67	38.24	37.25	37.27	32.36
12,	NPKcl	15.0	3.400	20.333	7.750	7.200	53.683	15.63	36.76	28.43	28.32	27.28
13,	0	12.0	2.500	19.167	7.667	5.667	47.000	18.75	33.33	22.53	15.45	22.51
14,	$N_{1\frac{1}{2}}PK$	12.0	4.833	17.750	10.000	6.875	51.458	16.67	33.00	24.51	27.10	25.32
15,	N_2PK	10.0	6.111	9.833	10.417	5.833	42.194	25.00	44.61	26.96	27.33	30.97
16,	$NKP_{1\frac{1}{2}}$	10.0	5.667	18.000	9.000	7.000	49.667	18.75	36.27	27.45	21.64	26.03
17,	0	10.5	3.167	20.333	9.667	7.000	50.667	22.66	33.33	23.04	18.33	24.34
18,	NKP_2	10.0	5.500	18.000	10.000	6.200	49.700	16.67	35.78	30.39	23.42	26.56
19,	$NPK_{1\frac{1}{2}}$	10.0	4.000	19.125	9.000	6.833	48.958	21.88	35.30	25.49	21.40	26.02
20,	NPK_2	12.5	4.200	20.000	6.833	7.333	50.867	25.00	43.63	31.37	29.24	32.31
21,	0	11.5	3.000	22.125	10.333	6.067	53.025	31.25	41.18	32.50	25.90	32.71
22,	0	11.5	3.125	–	10.800	–	–	28.13	–	–	–	–
23,	0	14.5	2.000	20.000	6.333	–	–	17.50	38.15	22.22	–	–

The area of each of these plots is 8 square rods.

Plots 1 5, 9, 13 17, 21, 22 and 23 are all untreated check plots. The meanings of the fertilizer symbols used in the table are as follows: —

0 = Nothing.
N = 100 pounds nitrate of soda per acre.
P = 400 pounds acid phosphate per acre.
K = 200 pounds high-grade sulfate of potash per acre.
L = 1 ton of lime (slaked) per acre.
Kcl = 200 pounds muriate of potash per acre.
$N_{1\frac{1}{2}}$ = 150 pounds nitrate of soda per acre.
N_2 = 200 pounds nitrate of soda per acre.
$P_{1\frac{1}{2}}$ = 600 pounds acid phosphate per acre.
P_2 = 800 pounds acid phosphate per acre.

In combination they mean, for example, as follows: N_2PK = 200 pounds of nitrate of soda + 400 pounds of acid phosphate + 200 pounds of high-grade sulfate of potash per acre.

The fertilizers were applied in the different years on dates as follows: 1911, middle of July; 1912, June 25 and 26; 1913, July 15; 1914, June 17 and 18 (except plot 12 and the lime on plot 11, July 17); 1915, June 26 and 28. The plots were all picked with scoops each year, on dates as follows: 1911, September 13 and 15; 1912, September 11 and 12; 1913, September 15 and 16; 1914, September 16 and 17; 1915, September 14 and 16.

The berries were run through a separator before they were placed in storage tests in 1912 and 1914. They were stored without separating in 1913 and 1915, — in the latter year as soon as they were picked. The percentages of loss in storage were obtained from measurements of the quantities of fruit at the beginning of the tests and after the screening was done at their close in 1912, 1913 and 1914. In 1915 they were obtained by averaging the results of the examinations of cup samples, taken from January 3 to 7, inclusive, the results of the sampling being shown in some detail in Table 3.

The figures in the table seem to show a moderate average increase in the quantity of fruit obtained during the five-year period from the fertilized areas as compared with that from the checks. The figures given for plot 15 are misleading, as half of that plot was used in spraying tests with Bordeaux mixture, there being a considerable reduction in its quantity of fruit some years as a consequence.

The average percentages of loss in the storage tests seem to indicate that the nitrate of soda impaired the keeping quality of the fruit somewhat, while no effect in this respect connected with the use of acid phosphate and sulfate of potash is apparent. It will be noted that the berries from the plot treated with lime did not keep at all well in 1914 and 1915 as compared with those from the other plots, though in the 1912 tests they showed about as little decay as any. It should be stated in this connection that a marked scattering of dead and dying vines developed on all parts of this plot in the late summer and fall of 1915, no other considerable area on the entire bog being thus affected. The vines showing this condition appeared entirely like those of the same variety (Early Black) on about ten acres of a bog a few miles away, the other varieties of which (Late Howe and Matthew) showed no such trouble. The Early Black berries picked on this other bog this season showed poor keeping quality both in storage and shipment. It perhaps may be inferred from this that lime favors the development of some disease that is peculiar to the Early Black variety.

The experiments with fertilizers to determine the possibility of stimulating and increasing the "setting" of cranberry blossoms, discussed in the last annual report of the substation (page 102), were continued and extended, one Early Black and one Late Howe plot (each of eight square rods) being treated in addition to the two areas used last year. On the station bog the blossoming period of the Early Black variety extended from July 1 to July 20, and that of the Late Howe from July 9 to July 26. The fertilizer was applied to the two Early Black plots on July 7, and was washed in by a good rain the following day. The Late Howe plots were treated on July 14, but no rain of any consequence followed the application until the 19th. The fertilizer was used on all these plots at the following rate per acre: 160 pounds of nitrate of soda + 400 pounds of acid phosphate + 200 pounds of high-grade sulfate of potash. The Early Black plots and their checks were picked on September 17 and 18, and the Late Howe on October 14, no very distinct advantage in quantity of fruit, on the whole, being shown by the fertilized areas. The berries from three of these plots were put in storage tests, and all showed an impaired keeping quality in comparison with the fruit from the checks.

INSECTS.

The black-head fire-worm caused about its normal amount of injury during the season. The loss caused by the fruit worm was considerably more than in either 1913 or 1914, but not as great as in some years. The false army worm (*Calocampa nupera* Lintner) has not been generally injurious for several years and was not much in evidence in 1915. The army worm (*Heliophila unipuncta* Haworth), which caused so much apprehension on account of its great abundance in 1914, dropped out of sight, as did also the forest tent-caterpillar (*Malacosoma disstria* Hübner) and the apple-tree tent-caterpillar (*Malacosoma americana* F.), both of which had been tremendously abundant in the cranberry region, as elsewhere, for several previous seasons.

A spanworm commonly seen on cranberry bogs in July, known to science as *Abbotana clemataria* Sm. and Abb.,[1] was reared successfully, the moths emerging between the 20th and 27th of May from pupæ formed between the 9th and 25th of July, 1914. One of the reared moths laid a batch of 432 eggs about May 30. The eggs were green when first deposited, but during the period of incubation they changed first to red, then to black, taking on the latter color only two or three days before they hatched. The young caterpillars emerged on June 14 and were mostly black in color. These worms full-grown were about 2½ inches long and of a fairly uniform chocolate-gray color. They went down to a maximum depth of 2 inches in the sand of the breeding cans to pupate. The pupæ were from 18 to 23 millimeters long and from 6 to 7 millimeters broad across the tips of the wing cases. Their general color was light chocolate-brown, with an irregular sprinkling of fine black spots, the spiracles and their immediate surroundings appearing as very noticeable black spots along their sides; but the wing cases were uniform light brown.

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[1] Identified by Mr. August Busck of the Bureau of Entomology, United States Department of Agriculture.

The adult moth measures, with wings spread, about 2 inches from wing tip to wing tip, and is of a light gray color moderately variegated with light brown, appearing as though it were lightly sprinkled over with pepper, with a straight white line running across the hind part of each fore wing, and a noticeable, though small, black spot in front of the middle of each wing. Though commonly seen on the bogs, the caterpillars of this insect have never been found by the writer in sufficient numbers to do any considerable injury. This is the fifth important species of cranberry-attacking spanworm that has thus far been reared, the other four being: *Cymatophora sulphurea* (Packard),[1] the green spanworm commonly found late in May eating holes in the winter buds at the tips of the uprights; *Epelis truncataria* var. *faxonii* Minot, discussed at length in the last two annual reports of the substation; the "chain-dotted geometer" (*Cingilia catenaria* Cram.), a bright yellow worm measuring about 1½ inches in length when full grown, commonly seen on cranberry bogs in small numbers in late July and early August; and the "cranberry spanworm" (*Cleora pampinaria* Gn.), fully discussed by Dr. John B. Smith in Farmers' Bulletin No. 178 of the United States Department of Agriculture. The writer, in eight seasons of cranberry investigation, has never found a caterpillar of the last-named species on any bog, and Prof. H. B. Scammell, after three years' work in New Jersey, has yet to find it there.

An Ichneumonid parasite, *Amblyteles putus* Cress.,[2] was reared from *Cymatophora sulphurea* in small numbers.

What appears to be an infestation by the "cranberry rootworm" (*Rhabdopterus picipes* (Oliv.)) was discovered in October on a bog in Wareham, some two acres showing more or less injury. This insect has not, heretofore, been known to be injurious on any Massachusetts bog, but it is an old and rather serious offender in New Jersey. No beetles have yet been reared in connection with the infestation found in Wareham, but specimens of the grubs and injured vines were sent to Professor Scammell, the entomologist investigating cranberry insects in New Jersey for the Bureau of Entomology of the United States Department of Agriculture, for comparison, and he replied concerning them: "Have just compared your larvæ with some alcoholics of mine and must say that I cannot detect any difference between them. The injury to the roots seems to be identical with that caused by *R. picipes* here, and I therefore offer the opinion that your specimens are *Rhabdopterus picipes* Oliv."

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[1] See Entomological News, Vol. XVIII, p. 17, 1907.

[2] Determined by Dr. J. F. Martin, who recently finished his postgraduate course at the Massachusetts Agricultural College, specializing with the Ichneumonidæ.

A bog injured by this insect has a general appearance similar to that of one damaged by the cranberry girdler (*Crambus hortuellus* Hbn.), the patches of dead vines being very irregular in form and distribution. Roots injured by the girdler, however, have the wood as well as the bark eaten considerably, frequently being entirely cut off, while the large and secondary roots worked on by the rootworm show practically no injury to the wood, only the bark being eaten away. The girdler feeds on the surface, concealed in fallen leaves or other trash which lies over the sand, and prefers the runners and crowns of the plants, while the rootworm works in the soil and feeds very largely on the fibrous roots which, though they form a dense mat an inch or more in thickness, are frequently almost completely devoured.

The bog area which has this newly discovered Massachusetts infestation is completely flowed every winter to a constant depth of about 9 inches. It has a peat "bottom" with first-class drainage during the growing season. It has been resanded every other year for the past ten years. When it was examined on December 8, most of the grubs were found just below the inch and one-half thickness of frozen surface sand, but they ranged to a maximum depth of 8 inches.

On September 16 the writer examined a bog in South Carver on which small beetles in great numbers had been for some time devouring the foliage. The infested bog was circular in form and had a total area of about five acres. One and one-half acres in the very middle part had been turned brown by the insect in a way to suggest, to one viewing it from some distance, a severe fire-worm attack. The beetles were mating very freely at the time and were also feeding on the cranberry foliage voraciously, the backs of the leaves receiving most of their attention, though the front side was also eaten considerably. A quantity of these insects was collected and preserved, and they have been identified[1] as belonging to the species known to science as *Cryptocephalus incertus* Oliv. The beetles are from about 2 millimeters to about 3 millimeters (from less than three thirty-seconds to about one-eighth inch) in length, the smallest specimens being males while the larger ones are females. As a rule, they are seal brown in color, though some of the females are almost black. Both sexes have rather conspicuous, though poorly defined, white longitudinal stripes on the wing covers.

The manager of the infested bog had noticed a considerable injury to the vines as early as the 20th of August, though he did not discover the beetles until a few days before the writer's visit. This fact, taken in connection with the very general mating observed, leads to the suspicion that much of the injury seen by the writer had been caused by the larvæ of the insect. The infested bog is eighteen years old, has been completely winter flowed every year for several years, this flowage having been let off between March 15 and April 1 in both 1914 and 1915, and has been resanded every other year for the past twelve years. It was reflowed in June as usual. Early Black and Late Howe vines were injured somewhat, but the variety most affected was the Chipman.

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[1] By Mr. E. A. Schwarz of the Bureau of Entomology of the United States Department of Agriculture.

As a matter of passing interest, it was noticed that the caterpillars of the apple sphinx moth (*Sphinx gordius* Cramer), usually found on the bogs in considerable abundance by the pickers, seemed to be almost entirely absent this fall, not a single one being found on the station bog where they were in evidence in large numbers in the fall of 1914.

The writer has observed the oyster-shell scale (*Lepidosaphes ulmi* L.) in more or less abundance on cranberry vines on dry bogs for several years, a rather seriously injurious infestation being occasionally found. This insect apparently never becomes very abundant on bogs that are winter flowed.

The Gypsy Moth (*Porthetria dispar* L.).

There are apparently four distinct ways in which a bog may become infested with this pest, as follows: —

1. *By the Hatching of Eggs deposited on the Bog the Previous Year.* — This is probably the principal source of trouble under present conditions. Egg masses on a bog in Carver which, having become completely flowed by the accumulation of rains to a depth of 10 inches by the 1st of February, had the water all pumped off by the 11th of April were observed by the owner to hatch fairly well afterward.

The writer collected a quantity of egg masses, all from the same general locality, and separated them into three approximately equal batches. One batch was placed in a can in the basement of the station screen-house for the winter as a check. The other two were submerged in 3 feet of water in a pond on January 14. One of these lots was taken out of the pond on April 1 and the other on May 20. Practically all the eggs kept in the screen-house hatched normally, while only about half of those taken from the water on April 1 and none of those taken out on May 20 hatched. These experiments indicate that late holding of the winter flowage (until May 20), when practicable, may be relied upon to wipe out an old infestation.

If, for any reason, late holding of the winter water is not desirable, reflowing will undoubtedly prove a satisfactory method of control where water supplies are abundant, if applied about May 20 and again about June 5, care being taken to kill by burning or by spraying with kerosene those caterpillars that succeed in floating ashore alive. If spraying must be resorted to, it should be done while the worms are yet in their early stages. Most of the eggs usually hatch between May 5 and May 18. To be most effective, the spraying should probably be done about May 15, and should, if the infestation is very serious, be repeated a week later to kill the worms that hatch afterwards. It is the writer's experience that caterpillars of the false army worm may be easily found in their very first stages by sweeping the vines hard with an ordinary insect collector's net, and the seriousness of an infestation determined by making counts of the worms thus captured. As the false army worm clings to the vines with much the same tenacity as the gypsy, it seems probable that an infestation by this insect may be estimated in the same way, and the advisability of spraying be thus ascertained. If an average of not more than 5 or 6 small false army worms are captured with 50 sweeps of the net, the infestation is usually not serious enough to call for spraying, while 15 or 20 worms caught with the same number of sweeps shows that spraying is pretty certainly necessary. It is presumed that similar counts will apply with the gypsy.

2. *By Wind Drift of the Worms in their Early Stages.* — It has been abundantly proved that the first instar worms of this insect are frequently carried several miles by strong winds, the long hairs with which their bodies are clothed causing them to be easily spread in this way. The period of their wind dispersal in large numbers usually extends from about May 14 to June 1. If, therefore, the winter flowage is held until about June 1, infestation by wind drift will be prevented. With present methods of bog management, however, it usually is not best to hold the winter water so late. Reflowing or spraying, as above indicated, will, therefore, have to be depended upon in most cases. Probably the June flooding commonly practiced for destroying the black-head fire-worm will be found satisfactorily effective in this connection.

3. *By Worms falling on Bog Margins from Overhanging Trees.* — The uplands around most bogs are now entirely cleared of trees and brush for some distance back from the bog margin. The chances of gypsy infestation in this way are, therefore, in most cases, very slight. To say, in this connection, that all bog margins should be entirely cleared of arborescent growths is superfluous.

4. *By the Caterpillars crawling across Marginal Ditches after they become Large.* — A serious infestation can come about in this way only when the surrounding upland is very heavily infested. It can probably be prevented by keeping the marginal ditch well cleaned out and partly filled with water. As the caterpillars are enabled by their hairs to float a long time before drowning, it may be necessary to cover the ditch water with a film of oil. Fuel oil would be cheap and probably effective for this purpose.

The Cranberry Tip Worm (*Cecidomyia oxycoccana* Johnson).

In July a large number of bogs were examined to determine the proportions of tips injured by the last brood of maggots, this being regarded as the best means of ascertaining the relative amounts of infestation. Table 17 shows the results of these examinations on fourteen different bogs, as compared with the findings of the 1914 investigation.

TABLE 17. — *Amount of Tip Worm Injury in 1914 and 1915. — Effect of Resanding.*

Bog.	Location of Bog.	Bog Dry or Winter Flowed.	Date of 1914 Examination.	Number of Tips examined in 1914.	Number of Tips found Injured in 1914.	Percentage of Injured Tips in 1914.	Date of Removal of Winter Flowage in 1915.	Bog sanded between September, 1914, and May, 1915, or not.	Date of 1915 Examination.	Number of Tips examined in 1915.	Number of Tips found Injured in 1915.	Percentage of Tips injured in 1915.
1, ...	East Wareham.	Winter flowed.	July 15	438	192	43.84	June 5	Sanded.	July 22	469	13	2.77
2, ...	East Wareham.	Winter flowed.	July 7	259	177	68.34	May 20	Sanded.	July 15	485	22	4.54
3, ...	East Wareham.	Dry.	July 7	119	29	24.37	-	Sanded.	July 22	462	64	13.85
4, ...	East Wareham.	Winter flowed.	July 13	174	22	12.64	May 11	Sanded.	July 23	371	18	4.85
5,[1]	East Wareham.	Winter flowed.	July 10	169	43	25.44	May 21	Sanded.	July 23	378	36	9.52
								Not sanded.	July 23	215	85	39.53
6, ...	East Wareham.	Winter flowed.	July 14	321	29	9.03	April 25	Not sanded.	July 24	245	67	27.34
7, ...	East Wareham.	Winter flowed.	July 14	468	51	10.90	April 25	Not sanded.	July 27	558	167	29.93
8, ...	East Wareham.	Winter flowed.	July 15	135	89	65.93	-	Not sanded.	July 26	638	43	6.74
9, ...	Carver.	Winter flowed.	July 13	305	209	68.52	-	Not sanded.	July 29	476	329	69.10
10, ...	East Wareham.	Winter flowed.	July 15	451	160	35.48	April 25	Not sanded.	July 25	463	157	33.91
11, ...	East Wareham.	Dry.	July 11	122	9	7.38	-	Not sanded.	July 23	259	87	33.59
12, ...	East Wareham.	Dry.	July 11	111	45	40.54	-	Not sanded.	July 23	311	156	50.16
13, ...	East Wareham.	Dry.	July 10	145	7	4.83	-	Not sanded.	July 22	362	53	14.64
14, ...	East Wareham.	Dry.	July 13	163	32	19.63	-	Not sanded.	July 23	208	80	38.46

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[1] As part of this bog was sanded while part was not, two separate examinations were necessary in 1915 in place of the one in 1914, which covered both parts. For each of the examinations, results of which are given in the table above, uprights were collected from many different well-scattered locations on the bog. They may, therefore, be considered to have represented the condition of the bog with reasonable accuracy in each case.

A comparison of the figures given in the table shows that there was not a single bog, a record of the 1914 examination of which was kept, that, after being resanded, did not show a tremendous drop in the amount of tip worm infestation. On the other hand, practically only one bog that was not resanded between September, 1914, and May, 1915, failed this year to have an infestation equal to or greater than that of 1914. The single exception (No. 8 in the table) was so heavily frosted late in May that its prospective crop was entirely destroyed and most of its tips killed back. In the opinion of the writer its exceptional condition as regards tip worm infestation was an effect of the frost injury, most of the maggots of an early brood perhaps having been starved to death by the drying up of the tips killed by the frost, this conclusion concerning the effect of frost being in line with those advanced in last year's report of the substation (page 106).

The examination this season of many other bogs besides those listed in the table produced abundant corroborative evidence of the marked effect of resanding on the subsequent amount of infestation by this insect.

In December, uprights from many locations on four different bogs were examined to determine the amount of recovery from injury done by this insect as indicated by the development of buds large enough to promise the production of blossoms therefrom the following season. The results of these examinations are shown in Table 18. The buds in the axils of the leaves, as well as those at the tips of the uprights, were included in making the counts.

TABLE 18. — *Winter Bud Formation subsequent to Tip Worm Injury.*

Bog.	Number of Tips examined.	Number found showing Tip Worm Injury.	Number showing Injury with Blossom Buds.	Percentage of Tips showing Injury with Blossom Buds.	Number not showing Injury with Blossom Buds.	Percentage of Tips not showing Injury with Blossom Buds.
1, ...	388	147	37	25.17	126	52.28
2, ...	760	142	26	18.31	334	54.05
3, ...	350	109	13	11.93	135	56.02
4, ...	228	38	19	50.00	169	88.95

It will be seen from the table that, while a much larger percentage of uninjured tips developed buds, there was, nevertheless, a sufficient recovery among those that were injured to cause a considerable bud production. In view of this and of the fact that the effect of light or heavy cropping is carried over in the vines from one season to another, it is very difficult to say, with any degree of accuracy, how great the loss caused by this insect one year with another really is.

The Black-head Fire-worm[1] (*Rhopobota vacciniana* (Pack.)).

Arsenical sprays, well sweetened with saccharin, were tried against this insect, but no advantage of any consequence resulting from the sweetening was detected.

The writer dislikes the idea of spraying for this pest. At best, it is an expensive and injurious method of treatment. The general conditions of the cranberry industry are making the use of less costly means of control than spraying increasingly imperative for this insect as well as for the other common pests and diseases. The possibilities in this connection are made more apparent in the discussion of bog management included in this report.

In last year's report (page 107), the writer suggested the possibility of treating this insect satisfactorily by holding the winter flowage late enough to kill its eggs, as often as an infestation developed sufficiently to do serious damage, sacrificing the crop in the years of such late holding. He has had the opportunity to observe the results of such late holding to some extent this season. A New Jersey bog appeared to be satisfactorily cleared of the pest by holding the water until the middle of June, and a heavy infestation on a bog in Wareham was very greatly reduced by the holding of a partial flowage until the 1st of July. In the latter case the results, under the conditions, were so satisfactory that it seemed certain that the bog would have been cleared entirely had all the vines been completely submerged. In neither case did the vines appear to be much injured by the water. Those on the Wareham bog bloomed considerably and came to the end of the season well budded and otherwise in good condition, even producing a little fruit.

The Cranberry Fruit Worm (*Mineola vaccinii* (Riley)).

Two netting sacks, each containing 160 cocoons (with worms) of this insect, were submerged in a pond in 3 feet of water on January 15. One of these sacks was taken from the water on March 31, and the cocoons were opened on the same day and their contents examined, 40 per cent. of the worms being found alive, almost a quarter of them being quite active. The other sack was taken from the water on May 20, and the contents of its cocoons were examined on the same day, not a single live worm being found, most of them being more or less decomposed. The results of these experiments are entirely in line with the common experience of cranberry growers, which has for years indicated that the fruit worm could not endure a prolongation of winter submergence far into the spring. If these tests show accurately what actually occurs on the bogs, we seem forced to the conclusion that most, if not all, of the infestation found on a bog in any season immediately following a late holding (until May 20) of the winter flowage comes from the upland that season and does not have its origin on the bog itself.

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[1] The American Association of Economic Entomologists, at its last annual meeting (December, 1915), voted to adopt the terms "black-head fire-worm" and "yellow-head fire-worm" as common names for this insect and *Peronea minuta* (Rob.), respectively, in place of the names "black-head cranberry worm" and "yellow-head cranberry worm" formerly officially recognized by it. As the writer finds the newly adopted names satisfactory, he abandons, in this report, the terms "flowed-bog fire-worm" and "dry-bog fire-worm," previously used by him for these insects.

In the opinion of the writer the temperature of the water is the principal factor in determining the effect of submergence upon the worms (in cocoons), though this has not yet been definitely proved.

The season's records show a considerably higher total parasitism for this insect than was found in 1914, but such a difference may not really have existed, as the study of the parasites was less advanced and less thorough last year than this. The records for this season seem fairly accurate, and the high percentages of parasitism found seem surprising. Special attention was given, as last year, to the three principal parasites: viz., the Braconid (*Phanerotoma tibialis*,[1] which parasitizes the worms), the Ichneumonid (*Pristomeridia agilis*,[2] also a worm parasite) and the Chalcidid (*Trichogramma minuta*, an egg parasite). The *Phanerotoma* parasitism was found to range this season from about 27 to 72 per cent. on dry bogs (without winter flowage), and from almost none to about 22 per cent. on bogs that had the winter flowage held late. The *Pristomeridia* parasitism ranged from about 5 to about 38 per cent. in fruit worms taken from dry bogs, and from none to about 7½ per cent. in those from bogs that had the winter flowage held late. Fruit worm eggs showed a range in *Trichogramma* parasitism of from 42 to about 89 per cent. on dry bogs and from about 12 to about 89 per cent. on those with winter flowage. It will be seen that the parasitism, as a whole, ranged, as in previous seasons, considerably higher on dry bogs than on flowed ones. As a result of these investigations, the writer estimates that all the natural insect enemies (including such predacious forms as spiders and ants with the three parasites here mentioned and other lesser ones not discussed) of the fruit worm took care this year of not less than 97 per cent. of the entire infestation on some dry bogs and of close to 90 per cent. on some flowed ones. The percentage probably ran considerably below these figures with most bogs, however, especially those with winter flowage.

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[1] There is some doubt about this specific name. Mr. A. B. Gahan, of the Bureau of Entomology of the United States Department of Agriculture, regards the species as being new to science.

[2] Specimens of this species were sent to Mr. A. B. Gahan, and he replied concerning them as follows: "Your specimens agree with *Pristomeridia agilis* Cress., except that they are considerably larger. I can find no character to distinguish them from that species other than size. They also appear to agree with the type of *P. euryptychiæ* Ashm. In size your specimens are more like the latter. I am unable to say whether *agilis* and *euryptychiæ* are the same species or not. So far as I can see they are alike structurally, and it may require a knowledge of their biologies to determine whether they are different. *Euryptychiæ* was supposedly reared from a lepidopterous gall maker on *Solidago*, and it would seem a little strange to find the same species parasitizing the fruit worm, although not impossible. The parasitism of *agilis* is apparently unknown. You had perhaps best use the name *agilis* for your species for the present."

In a second letter, written after he had examined the smallest specimens of the species which the writer could find, he added the following information: "Your specimens agree nicely with the type of *euryptychiæ* in size as well as structure, but your smallest specimen is still much larger than the type of *agilis*. I am strongly inclined to think that the two species are synonymous, but would like to have specimens showing better the gradation in size from one to the other before stating that they are the same."

It will be observed that late holding of the winter flowage appeared to greatly reduce the *Phanerotoma* and *Pristomeridia* parasitism. The writer is inclined to regard this reduction as another rather reliable indication that most of the infestation which appears on a bog, during a season immediately following a late holding of the winter flowage, comes from the upland rather than from the bog itself. Fruit worm moths appear to have fairly good powers of flight, and, if they come from considerable distances to a bog which has been cleared of parasites by the late-held winter flowage, they may succeed in eluding their worm parasitism to no little extent. This reduction of the *Phanerotoma* and *Pristomeridia* parasitism appears to explain the fact that the effect of the late holding of the winter flowage in any season, in its reduction of fruit worm infestation, does not endure into the following season as well as might be desired.

Thirty-five fruit worm cocoons which had been kept in the basement of the station screen-house all winter were opened on May 28 and their contents examined, 30 live and 5 dead worms being found, no pupa of either fruit worm or parasite being present. On June 19, 40 more cocoons similarly cared for during the winter were opened and found to contain: 18 parasite cocoons, part of them being *Phanerotoma* and part *Pristomeridia* (the adults of both parasites emerging between June 26 and July 6); 12 fruit worm pupæ; 1 fruit worm containing a parasite, apparently *Phanerotoma* about three-fourths grown (the worm being torn open to determine this); 1 live unparasitized worm and 8 dead worms. It thus appears that the fruit worm and its two principal worm parasites begin their pupation period at the same time, the change taking place, for the most part, during the first half of June.

As a rule, only one or two of the black eggs of *Pristomeridia* are found in a fruit worm parasitized by that species, but in exceptional cases three or even four are deposited.

Phanerotoma females were induced to parasitize, under observation, eggs of the fruit worm which had been laid in captivity a few hours before. To toughen the eggs so that they might be easily removed for microscopic examination, the berries on which they were deposited were placed at once in commercial alcohol for several hours. When the eggs thus treated were examined, the *Phanerotoma* eggs which they contained were easily found. The latter were elongate and rounded at the ends, nearly transparent, very delicate and pliable, and without any noticeable markings. They usually appeared curved from end to end, as they lay in the host eggs, but were nearly straight when crushed out of the abdomens of the females. The results of this study show that the idea that this parasite was viviparous, advanced in last year's report (page 109), was erroneous.

Fruit worm eggs laid the night of July 19 and parasitized under observation by *Phanerotoma* females the morning of the 20th were examined microscopically the morning of the 24th, five larvæ of the parasite being found to have hatched. The incubation period of this parasite is certainly, therefore, not longer than four days, and may be considerably shorter than that.

Seven eggs laid by fruit worm moths in captivity some time between 8 P.M. July 18 and 8 A.M. July 19, 1915, were parasitized under observation by *Phanerotoma* females between 9 A.M. and 12 M. July 19, and all of them hatched between 4 P.M. July 26 and 8 A.M. July 28, four doing so before 8 A.M. July 27.

The idea, advanced in the last annual report (page 112), of increasing the natural effectiveness of the Braconid (*Phanerotoma*) parasites by harboring them artificially during the winter is found to be impracticable principally because of the interference of the Chalcidid (*Trichogramma*) parasite, as the latter develops as readily in fruit worm eggs in which *Phanerotoma* eggs have been deposited as in those which have not been attacked by that parasite, and when both parasites attack the same egg the Braconid is destroyed by the very rapidly developing Chalcidid. As the Chalcidid is considerably the more abundant parasite of the two, this interference is sufficient to very largely nullify whatever advantage might be gained with considerable effort in the way suggested.

As is shown by Table 19, the examination of fruit worm eggs from a number of bogs that were reflowed in June and from adjoining ones that were not reflowed seemed to indicate that the flowing in some way not apparent had the effect of increasing the *Trichogramma* parasitism very markedly. This, however, did not appear to result in the corresponding decrease in fruit worm injury that might reasonably have been expected. Possibly the destruction of predacious forms (ants, spiders, etc.) caused by the reflow largely offset the advantage that otherwise would have been obtained from the increase in parasitism.

TABLE 19. — *Effect of June Reflow on Amount of Trichogramma Parasitism.*

TESTS.	Examination.	Date of Examination.	Bog.	Date of Removal of Winter Flowage.	Date reflowed (June).	Number of Fruit Worm Eggs examined (both Hatched and Unhatched).	Number of Eggs found Parasitized (both Emerged and not Emerged).	Percentage of Eggs found Parasitized.
A (four adjoining Onset bogs),	1	Aug. 10	1	April 15	Not reflowed.	57	7	12.28
			2	April 15	13th.	20	13	65.00
			3	April 15	15th.	34	23	67.65
			4	April 15	16th.	40	30	75.00
	2	Aug. 16	1	April 15	Not reflowed.	20	5	25.00
			2	April 15	13th.	25	19	76.00
			3	April 15	15th.	27	22	81.48
			4	April 15	16th.	9	8	88.88
B (adjoining Smalley bogs), .	1	Aug. 17	1	April 12	Not reflowed.	5	0	-
			2	April 15	5th.	8	7	87.50
C (adjoining Hammond bogs),	1	Aug. 17	1	April 12	Not reflowed.	23	0	-
			2	April 14	3d	14	4	28.57
D (adjoining woods pieces bogs),	1	Aug. 20	1	April 15	Not reflowed.	192	58	30.21
			2	April 15	4th.	63	49	77.77
E (adjoining Bumpus bogs), .	1	Aug. 20	1	April 20	Not reflowed.	23	8	34.78
			2	April 20	4th.	70	55	78.57

Winter-flowed bogs that were not reflowed showed a much lower percentage of *Trichogramma* parasitism this season than did the strictly dry bogs (without winter flowage), a condition which perhaps might be expected.

A single specimen of *Megastigma brevicaudis* Rat.[1] and six specimens of an undetermined species of *Syntomaspis*[1] were obtained on July 2 and 3, 1907, from cans containing fruit worm pupæ in the cocoons. It is uncertain whether these Chalcidids were primary or secondary parasites.

In tests conducted the latter part of August, fruit worms fed freely on the following kinds of fruit: swamp blueberries (*Vaccinium corymbosum* L.), dangleberries (*Gaylussacia frondosa* (L.) T. and G.), black huckleberries (*Gaylussacia baccata* (Wang.) C. Koch), apples (*Pyrus malus* L.), and beach plums (*Prunus maritima* Wang.). They ate black cherries (*Prunus serotina* Ehrh.) very sparingly and the berries of *Viburnum cassinoides* L. not at all. They would not feed in confinement on cranberry leaves.

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[1] Determined by Mr. A. A. Girault of the Bureau of Entomology of the United States Department of Agriculture. The *Syntomaspis* species could not be identified definitely on account of the present chaotic condition of the genus.

Bog Management.

The cranberry investigations have now been carried on at the substation for six years. Each year has added something to the knowledge of the problems connected with the growing of this fruit. Many of the findings taken by themselves may seem to have no practical significance, but a stage in the work has now been reached in which the writer is beginning to assemble results in the hope of coming to definite conclusions as to what general changes in bog management, if any, are advisable. Certain ideas in this connection have presented themselves during the past year, and it seems best to discuss some of them in this report. It should be understood, however, that these ideas are not advanced as methods that have been proved to work to advantage. They are brought out here merely for the consideration of Massachusetts growers and in the hope that some will assist in testing them by trying them out on their own bogs.

The interest of the cranberry grower is seldom confined to the control of any one pest or to the solution of any other one problem of the industry as a thing by itself. His main business is not fighting fruit worms, but raising cranberries. The cost of resanding interests him less than the annual net return from his crop. In dealing with the many difficulties connected with the business, he must, if he is to succeed, keep clearly in mind the fact that his main problem — the problem which ultimately will command his every endeavor and around which all his minor interests must center — is really this: *How to make cranberry growing pay the largest possible net return on the capital invested.*

The net return is what is left of the proceeds of the sale of the berries after the cost of production and marketing has been taken out. With a given amount of capital invested and a given acreage under cultivation, this return may be increased either by a rise in the selling price of the fruit, the cost of production and marketing being more or less fixed; or by a lowering of the cost of production and marketing, the selling price being comparatively fixed; or by an increase in the selling price accompanied by a reduction in the cost of production and marketing. To enlarge upon these self-evident facts would be superfluous. They are only a part of the common experience in every walk of life. A man may "get ahead" in the world either by the good fortune of an increased income or by simplicity and economy in living.

In its beginnings, the cranberry industry was in the position of a man blessed with a large income, because cranberries commanded high prices in the markets. Strict economy was not, therefore, absolutely essential to success. During the last few years, however, prices have been comparatively low, and there seems to be no immediate prospect of their permanent return to higher levels. Cranberry growing has, therefore, now reached the stage where it is necessary to learn to produce the fruit and market it at the least possible expense to make sure of getting satisfactory returns. In other words, the industry is now in the position of a man who must live simply in order to succeed.

Much has been said recently about advertising cranberries extensively with a view to enlarging the market by this means. While the possibilities connected with advertising should not be overlooked, cranberries probably will not be found to be an exception to the general rule that good fruit is its own best advertisement. The growers of other kinds of fruit have made tremendous strides during the past decade in the attention which they give to the quality and condition of their products. Cranberry growers probably will find before long that they must give a like attention to the quality of their fruit if they are to compete successfully. Some of the things which should receive attention in this connection have already been mentioned in the discussion of the storage tests, and many other improvements in the methods of preparing cranberries for market are doubtless possible. The growers could probably do much to extend their market and maintain prices by giving their united attention to these neglected features of the business.

With the general conditions at present attending the cranberry industry brought to mind by the foregoing remarks, the reader will be in a position to more clearly comprehend the main problem of the cranberry grower if it is restated in this way: *How to grow and market cranberries of superior quality with the least possible expense.*

It is in connection with the matter of the reduction of expense in the growing of cranberries that the writer is here about to suggest a new plan of bog management. To begin with, it must be stated that the contemplated changes in methods probably cannot be applied with satisfactory results on all bogs. They may not be feasible on bogs with exceptionally rich bottoms, on account of the tendency to excessive vine growth. They may not be justified on bogs that produce average annual crops of over 60 barrels to the acre. Most bogs, however, do not produce a yearly average of 60 barrels per acre. The suggestions are therefore advanced with considerable confidence that they may be applied by most Massachusetts growers.

The idea of the writer is this: *Growers are unwise in attempting to raise a crop of cranberries from the same area every year.* In so doing they go to needless expense in the care of the bogs and the harvesting of the berries, and frequently throw away money in only partially successful attempts to control the insect pests. *In the opinion of the writer a substantial reduction in the cost of growing cranberries could be effected, without lessening the per acre production, by the adoption of the plan of cropping only every other year as a regular program.*

To begin the argument in favor of cropping every other year instead of every year, the writer will make this statement for the consideration of Massachusetts cranberry growers in general, for their approval or disapproval: If any bog that does not yield an average annual crop of more than 50 barrels to the acre fails completely to produce a crop one year (the vines being uninjured), it will, if it is properly cared for and meets with no accidents (such as frost, fire, hail or excessive insect injury), yield the following year at double its average annual rate of production. If this assertion is correct, it goes without question that the plan of cropping every other year may be adopted without fear of reducing the average yearly production of a bog. On the other hand, the writer proposes to show how an actual increase in production might result from such a change.

If the plan of cropping every other year were adopted, it would probably be carried out in somewhat different ways on different classes of bogs. In any case, it would call for the deliberate prevention of the development of a crop, in some way, by the management of the flowage, every other year. *For bogs abundantly supplied with water for reflowage* the writer suggests the following program: —

Begin by resanding the bog some fall after it has produced a heavy crop. This will reduce the tip worm infestation for the following season to a minimum, with the result that, barring accident, a good bud formation will be assured. Hold the winter flowage the following spring until the 20th of May, thus reducing to a minimum the fruit worm infestation already on the bog. Then reflow in June to destroy the first brood of the black-head fire-worm, and again in July to kill out whatever there may be of a scattering second brood. Reflow in full bloom for as long a time as may be necessary to destroy the prospective crop, and, finally, reflow for two or three days some time in August to destroy whatever girdler worms may be at work.

Treated in this way, the bog should be practically entirely free from insect enemies when it is flooded for the winter. It should be free from the fruit worm as well as from the other important pests, for the worms of the previous year will have been drowned out by the late holding of the winter flowage, and whatever subsequent infestation may have come from the upland will have perished or gone elsewhere because of the lack of food on the bog. In addition to being free from insects, the bog should have a maximum bud development for the following year, as the vines, not having been called upon to produce a crop, will be full of strength, and the tips will have had no chance to be injured to any extent by either the fire-worm or the tip worm. Moreover, the good condition of the vines will not have been impaired by the disturbance incident either to the picking of a crop or to resanding. The bog should, therefore, start the following season, the season in which the crop is to be produced, in the best possible condition in every respect. Under such conditions a bog could hardly fail, barring accident, to produce its maximum crop. It will be seen that this program calls not only for the prevention of the development of the crop every other year, but also for the using of every opportunity, in the year of nonproduction, to definitely prepare the bog, in every possible way, to do its utmost the following year.

For bogs which are winter flowed but cannot be reflowed the following plan of procedure is suggested: —

Begin, as before, by resanding the bog some fall when its general condition promises a light crop for the following season, to reduce the tip worm infestation. Hold the winter flowage the following spring as late as may be necessary to exterminate the black-head fire-worm and destroy the prospective crop. Just how late the flowage would have to be held to accomplish these two objects cannot yet be stated, but the 1st of July would probably, as a rule, be about the right date to let the water off. This late holding of the winter flowage would clear the bog of the fruit worm and probably of the girdler also, and the vines, not being taxed by a crop, would have abundant opportunity to develop and bud for the winter; and there should be, as on the bogs with reflowage above discussed, no considerable interference with the bud development from either the tip worm or the fire-worm.

These suggestions may seem unwise on account of the great danger of frost injury on bogs of this class. It is true that, with the proposed changes in the management of these bogs, means of frost protection would have to be provided to insure the crop when produced. Unfortunately, as stated on the first page of this report, tobacco shade cloth has not yet proved its usefulness for this purpose; but, with most bogs of this class, a satisfactory method of protection would probably be afforded by the conservation and proper handling of the winter flowage by means of low dikes and small pumping plants, the bogs being divided and a crop being produced on one part of their area one year and on the other part the next year. The flowage would be conserved on the part which was not producing a crop and would be let on to the part where the crop was being produced, when protection from frost was needed, and then be pumped back again. Handled in this way the winter flowage could be conserved to a far greater extent than is at present possible, for when it was all pumped on to one part of the bog its surface would be greatly reduced and its evaporation consequently be much lessened. It might be necessary in some cases to offset the loss from evaporation and seepage by providing a small accessory water supply by pumping through a small pipe, perhaps for some distance, either from the ground or from a pond or stream. Drainage, while the water was being held, would usually have to be accomplished by pumping.

The possible advantages connected with cropping every other year on flowed bogs may be summed up under the following heads: —

1. *Care of the Bogs.* — The weeds probably would be considerably reduced by the late holding of the winter flowage and a small reduction in expense thus effected.

Resanding every other fall is suggested above as a part of this program. The sanding plots on the station bog have seemed thus far to show that the main advantages of resanding, aside from that of providing a certain degree of frost protection, are its effects in keeping down the tip worm and the girdler. With the new scheme of management these insects probably might be satisfactorily controlled by the very late holding of the winter flowage, and frequent resanding be thereby rendered unnecessary. As the writer's experiments have shown that resanding has a strong tendency to injure the keeping quality of the fruit, it will be seen that, with this plan, the advisability of the use of sand, after a bog has become well vined over, would be strictly on probation. If resanding could be dispensed with, a considerable saving of expense would be realized.

2. *Treatment of the Insect Pests.* — In the new scheme of management no spraying in connection with any of the more common insect troubles, except on strictly dry bogs, is called for, water being relied upon entirely to control all these enemies on all bogs with winter flowage. Spraying might, of course, have to be resorted to occasionally in dealing with outbreaks of spanworms, army worms or cutworms, and the gypsy moth might also sometimes have to be treated in that way. Spraying is expensive, and the mechanical injury done to the vines and prospective crop in the operation is usually considerable. Moreover, it is at best only a partially successful treatment for any of the flowed bog pests.

Water used in the ways suggested should be entirely effective against all of the commonly injurious cranberry insects, with the possible exception of the fruit worm. Promising as it does to be by far the most effectual means of treatment, it is, at the same time, a general remedy which may be used with a minimum of expense and injury. This change in the methods of insect treatment would in itself, in the long run, make possible a considerable saving in expense.

With the methods of management at present in vogue, the fruit worm takes a considerable toll on most Massachusetts bogs every year. The amount of its injury on a bog in any season depends not upon the number of berries that are being produced, granted there are enough to keep the worms from starving, but upon the number of fruit worms that are at work. It will be seen, therefore, that, if the plan of producing a crop only every other year is adopted, the vines being nearly or completely barren on the alternate years, this insect will thereby certainly be cheated entirely out of one year's feeding every other year. Those who realize how great the average yearly loss caused by the fruit worm is will appreciate how such a reduction in its work might result in a substantial increase in the average quantity of fruit obtained. As the damage done by this insect in the year that the crop was produced would be reduced to a minimum, as already indicated, it having been both drowned out and starved out on the bog the year before, it seems evident that, under this system of management, as inexpensive and as satisfactory a means of control would be had as could be hoped for.

3. *Quality of Fruit produced.* — No one can tell how the keeping quality of cranberries would be affected by the changes in management here proposed until they have been tried out. This is a feature of the program that deserves the most careful investigation and consideration, for, as long as

the matter of spraying for the control of fungous diseases is in abeyance, proper methods of bog management will have to be relied upon as far as possible in producing fruit of superior inherent keeping quality. Much investigation is needed in this connection, especially concerning the bearing which water, in its various uses, has on the development and spread of fungous diseases.

It seems certain that, under this plan, less green fruit would be put on the market, for the winter flowage would seldom be held late on a bog in the spring of a season in which a crop was to be produced, and the berries would always have a growing season of good length before picking time came, as a result. There would also be much less trouble with fruit worms in the early shipments, for there would always be the combination of a maximum crop with a minimum infestation by this pest, this resulting in a great dilution of the infestation.

4. *Expense of Harvesting.* — The cost of picking a small crop is large out of all proportion to the quantity of fruit obtained, for the same area of ground has to be gone over whether the crop is large or small. With the plan of management here proposed, only maximum crops would ever be picked, the expense of harvesting being reduced thereby to a minimum. Moreover, bogs would be picked and also raked after picking only once where now they have to be gone over twice. In the opinion of the writer, the saving gained in this way would, as a rule, hardly be less than 35 cents a barrel.

Possibility of applying the New Plan to Dry Bogs.

Thus far the new proposals have been discussed only as they may apply to flowed bogs. Though the acreage of strictly dry bogs is relatively very small, the changes in question should, nevertheless, be considered in connection with them. It seems possible that these changes may be applied satisfactorily to such bogs, if the bloom can be effectually killed by spraying with iron sulfate or some other chemical. The investigations in this direction have not yet progressed far enough to justify a conclusive report. As has been shown, the fruit worm is very heavily parasitized on such bogs, and it seems only reasonable to suppose that, if it could be even partially starved out every other year, its parasites might thereby receive the assistance they need in order to get the upper hand of the pest sufficiently to reduce it satisfactorily. Careful attention is being given to this apparent possibility of tipping the balance of nature in favor of the cranberry grower. In the opinion of the writer, however, it will eventually be found advisable to replace the cranberry, on all bogs that cannot be winter flowed, with some other fruit-producing plant that does well in acid soil, such as the swamp blueberry (*Vaccinium corymbosum*).

BULLETIN No. 169 SEPTEMBER, 1916

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

CONNECTICUT VALLEY ONION SUPPLY AND DISTRIBUTION

By ALEXANDER E. CANCE, WILLIAM L. MACHMER
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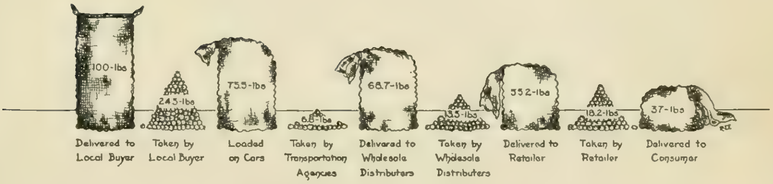
Department of Agricultural Economics, Massachusetts Agricultural College



The cost of marketing Connecticut valley onions. (See page 117.)

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Publication of this Document
approved by the
Supervisor of Administration.

BULLETIN No. 169.

DEPARTMENT OF AGRICULTURAL ECONOMICS.

CONNECTICUT VALLEY ONION SUPPLY AND DISTRIBUTION.

BY ALEXANDER E. CANCE, WILLIAM L. MACHMER AND FREDERICK W. READ.

PART I.

SUPPLY AND PRODUCTION.

Quantities and Regions of Production.

The production of onions is widely distributed. They are grown to some extent, at least, in every State in the Union. Well adapted to commercial production on a small scale the onion industry has shown a steady growth year by year, until, in 1914, with a yield of about 22,000,000 bushels, valued at $20,000,000, it ranked second among the truck crops of the United States.

The geographical distribution of the onion crop in the United States for the year 1909 is shown on the accompanying map reproduced from the report of the United States Census (Fig. 1). A second map (Fig. 3) shows the geographical distribution of surplus production for the year 1914, as reported by the Bureau of Crop Estimates.

A careful study of these maps plainly shows that the commercial onion-growing area is confined to three well-defined sections: first, the tier of States running westward from Massachusetts to Iowa; second, the Pacific Coast States, California, Washington and Oregon; and third, the southern States, Texas and Louisiana. The first and second groups include the States producing late onions, while the third is the home of the Egyptian and Bermuda varieties.

The total onion acreage of the United States in the census year 1899 was 47,981 acres. Seventeen States included in the above groups had

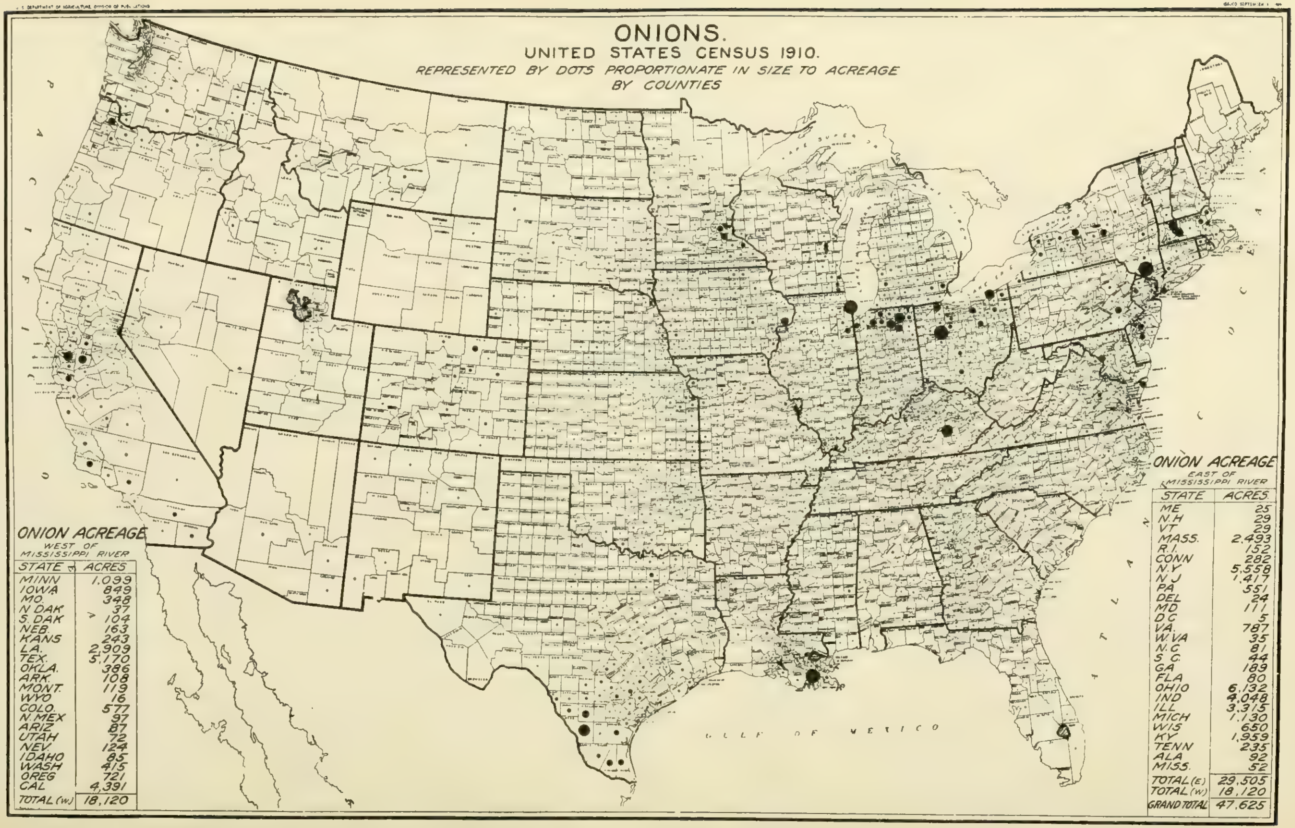
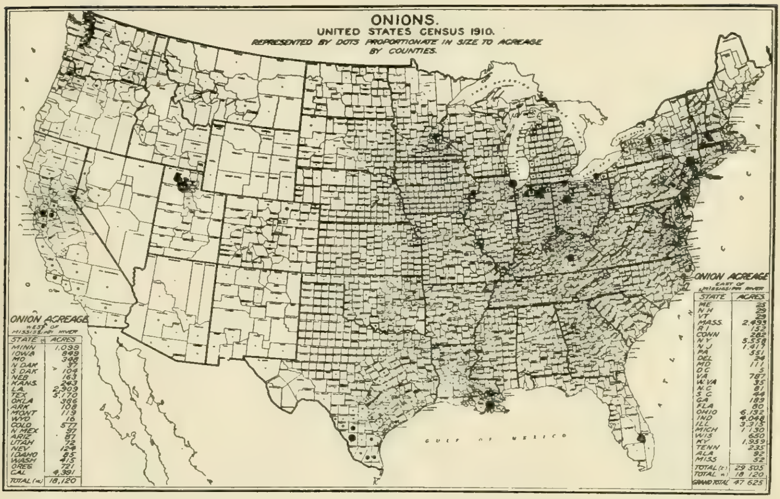


FIG. 1.—Commercially, onions are confined to (1) the States from Massachusetts westward to Iowa, (2) the Pacific coast States and (3) the Gulf States


ONIONS.
UNITED STATES CENSUS 1910.
REPRESENTED BY DOTS PROPORTIONATE IN SIZE TO ACREAGE BY COUNTIES.
GULF OF MEXICO

ONION ACREAGE WEST OF MISSISSIPPI RIVER

STATE	ACRES
MINN	1,099
IOWA	849
MO	348
N DAK	37
S DAK	104
NEB	163
KANS.	243
LA.	2,909
TEX	5,170
OKLA	386
ARK	108
MONT	119
WYO	16
COLO	577
N MEX	97
ARIZ	87
UTAH	72
NEV	124
IDAHO	85
WASH	415
OREG	721
CAL	4,391
TOTAL (W)	18,120

ONION ACREAGE EAST OF MISSISSIPPI RIVER

STATE	ACRES
ME	25
N H	29
VT	29
MASS.	2,493
R I	152
CONN	282
N Y	5,558
N J	1,417
PA	551
DEL	24
MD	111
D C	5
VA	787
W VA	35
N C	81
S C	44
GA	189
FLA	80
OHIO	6,132
IND	4,048
ILL	3,315
MICH	1,130
WIS	650
KY	1,959
TENN	235
ALA	92
MISS	52
TOTAL (E)	29 505
TOTAL (W)	18 120
GRAND TOTAL	47 625

FIG. 2. — The distribution of the onion crop in 1909. This map shows the onion-producing areas in 1909. The dots are proportionate to the acreage.

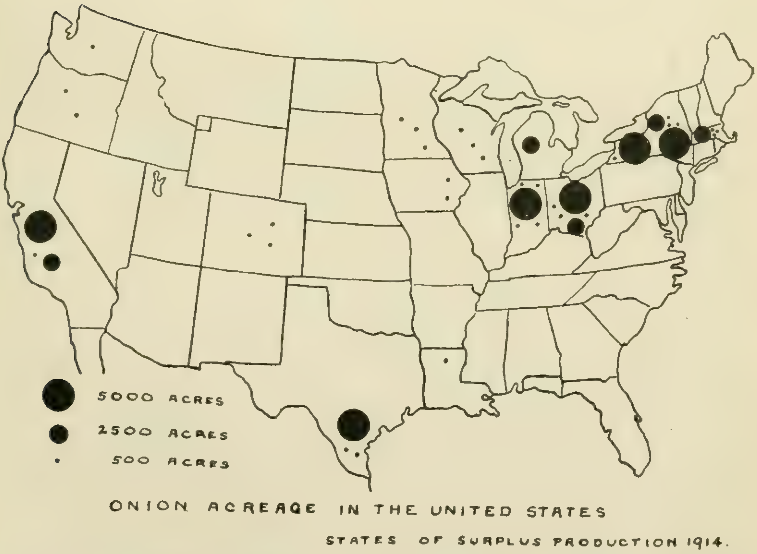

5000 ACRES
2500 ACRES
500 ACRES
ONION ACREAGE IN THE UNITED STATES
STATES OF SURPLUS PRODUCTION 1914.

FIG. 3. — The surplus onion States. The relative importance of the various commercial onion-growing States in 1914 is indicated by the black dots. Note the competitor directly west of Massachusetts.

36,599 acres, or approximately 76 per cent. of the total crop. In 1909 the total acreage in the 17 States of largest production was 43,151 acres, or 90 per cent. of the total onion acreage in the United States.

The States of surplus production and their onion acreages were as follows: —

STATES.	Acreage in 1899.	STATES.	Acreage in 1909.
New York,	6,033	Ohio,	6,132
Ohio,	5,067	New York,	5,558
Michigan,	2,611	Texas,	5,170
Illinois,	2,563	California,	4,391
California,	2,207	Indiana,	4,048
Indiana,	2,105	Illinois,	3,315
Kentucky,	1,705	Louisiana,	2,909
Virginia,	1,701	Massachusetts,	2,439
Massachusetts,	1,670	Kentucky,	1,959
Louisiana,	1,655	New Jersey,	1,417
Texas,	1,639	Michigan,	1,130
Pennsylvania,	1,505	Minnesota,	1,099
Missouri,	1,383	Iowa,	849
Wisconsin,	1,230	Virginia,	787
Connecticut,	1,206	Oregon,	721
Iowa,	1,195	Wisconsin,	650
Tennessee,	1,124	Colorado,	577
Total acreage,	36,599[1]	Total acreage,	43,151[2]

In 1909 Connecticut, Pennsylvania, Missouri and Tennessee were displaced by New Jersey, Minnesota, Oregon and Colorado.

The total area in onions in 1914 was 54,476 acres in the 12 States of surplus production. Their estimated onion acreage in 1916, excluding Wisconsin, was 31,548. These 12 States produced 69 per cent. of the total onion crop in the United States in the census year 1909. The yield in 1914 was 21,901,000 bushels, as compared with the yield of 9,962,012 bushels for 1915, and the estimated yield of 10,852,873 bushels for 1916. It should be noted that in the above estimate only States producing late onions are included. Texas, with approximately 10,000 acres devoted to onions of the Bermuda variety, is omitted.

---

[1] Seventy-six per cent. of entire acreage.

[2] Ninety per cent. of entire acreage.

Acreage and Production of Onions in the States of Surplus Production.

States.	Acres.			Production (Bushels).		
	1916.[1]	1915.	1914.	1916.[1]	1915.	1914.
Massachusetts,	3,800	3,923	4,388	1,406,000	1,357,358	2,018,480
New York,	9,389	12,551	14,339	2,722,810	3,602,137	6,567,262
Ohio,	5,302	2,667	9,014	1,834,492	272,034	3,605,600
Indiana,	4,666	3,070	6,801	1,586,440	564,880	2,210,325
Michigan,	873	933	2,633	282,852	223,920	971,577
Wisconsin,	–	1,940	1,384	–	679,000	433,192
Minnesota,	788	1,027	1,572	258,464	385,125	509,328
Iowa,	580	527	976	155,440	210,800	351,360
Colorado,	400	388	1,598	96,000	151,708	559,300
Washington,	613	581	1,112	312,630	232,400	444,800
Oregon,	737	691	735	283,745	276,400	260,190
California,	4,400	5,350	9,924	1,914,000	2,006,250	3,969,600
Total,	31,548	33,648	54,476	10,852,873	9,962,012	21,901,014

General Periods of Shipments.

With the marked expansion of the onion industry the market has shown an equally remarkable growth. Onions are now in the market all the year round. Coming out of storage in the winter, the storage onions are followed by the Bermuda, Spanish, Egyptian and Mexican shipments early in the spring, and later by those from Texas, Virginia, Maryland, Kentucky and Long Island, before the main crop of late onions from the commercial onion-growing sections of the United States reaches the market.

The Texas onion crop usually begins to move the last week in March. Heavy shipments begin about April 10 and continue until the middle of June; the last shipments to New York are made about the last week in July. The Louisiana onions make their appearance the last week in April. After the second week in May practically all the old stock of late northern onions is closed out. From the first of June, Texas, Bermuda, Egyptian and Spanish onions constitute the principal offerings until the beginning of July, when Kentucky onions are shipped north. About the same time Jersey, Maryland, Virginia and some California and Mexican onions appear. During the third week in July, Connecticut Valley "sets" arrive on the New York market. Through August, September, October and November, heavy importations of Valencia and Denia onions make them a competing factor in the principal markets.

---

[1] Estimated.

Late California and Washington onions do not get to the eastern markets much before the middle of August.

Beginning early in September, Connecticut Valley, Orange County (N. Y.), Ohio and Long Island more than supply the demand. Heavy shipments of these varieties from the field continue until about the middle of November. Connecticut Valley storage onions, as well as those from New York and Ohio, begin to appear in December and continue to move freely through January, February, March and April. Storage onions begin to move in quantity from Michigan and Indiana about the first of February. These supply the markets of the middle west. The southern crop is a competing factor during April and May, and Cubans and Bermudas cut some figure also before the entire crop from the northern part of the United States is consumed. A late southern crop decidedly helps the northern storage men. The duration of the onion-shipping season for the principal States is about as follows: —

Massachusetts,	Middle of July to May 1.
New York,	August 15 to May 1.
Ohio,	September to May.
Michigan,	September 1 to March 20.
Indiana,	October 1 to March.
Wisconsin,	September 10 to March 20.
Minnesota,	October 1 to November 1.
Iowa,	July to April.
Illinois,	October 1 to March.
Colorado,	September to December.
Washington,	September to November 20.
Oregon,	September 7 to March 15.
California,	At intervals throughout the year from different sections.
Texas,	April 10 to July 25.

Reports received by the United States Department of Agriculture from 209 shipping points in the 16 late onion-producing States show that 18,943 cars of onions were shipped in 1913, of which 12,239 cars were moved directly from the field, and 6,695 went into storage at these points for later sale. In 1914 approximately 21,653 cars were shipped from these points, of which 7,879 cars went into storage. In 1913 and 1914 these 16 States produced 75 per cent. of the total onion crop.

Onion Districts in Massachusetts.

The accompanying maps (Figs. 4 to 8), compiled from the Massachusetts Census reports, indicate the distribution of the Massachusetts onion districts at ten-year intervals from 1865 to 1905. Figs. 9 and 10 show the acreage and production of the Connecticut Valley in 1914 and 1915. The data for these were collected in the field by the writers. In 1855 the

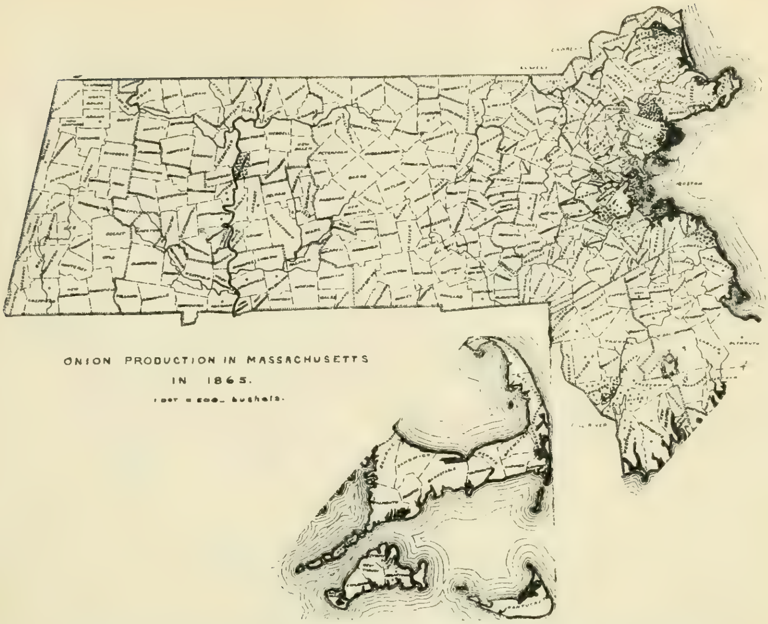


FIG. 4. — The distribution of Massachusetts onions by towns in 1865. Practically none west of the Connecticut River.

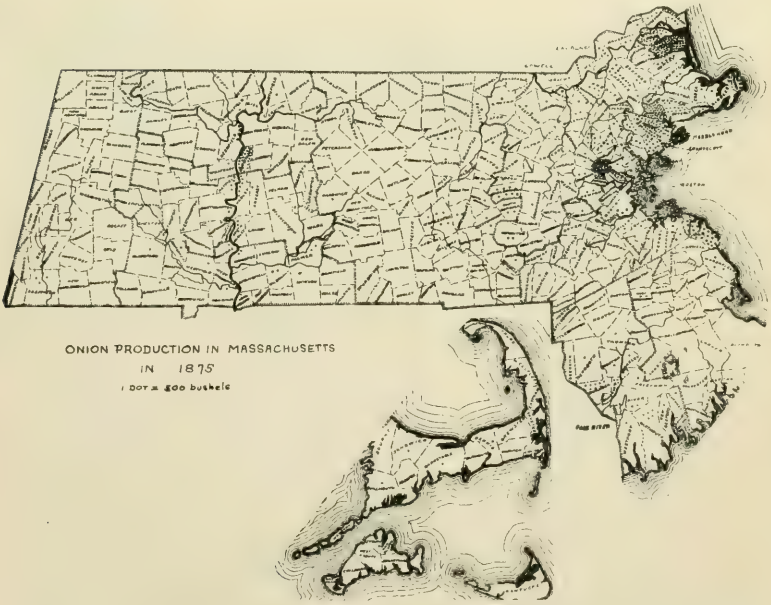


FIG. 5. — The Massachusetts onion crop in 1875. It still belongs largely to Essex County.

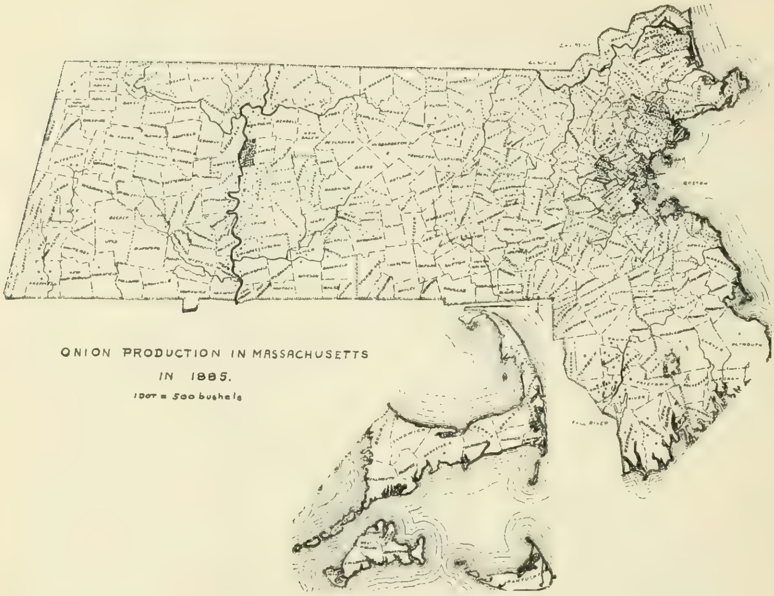


FIG. 6. — The Massachusetts onion areas in 1885. Sunderland shows a decided gain.

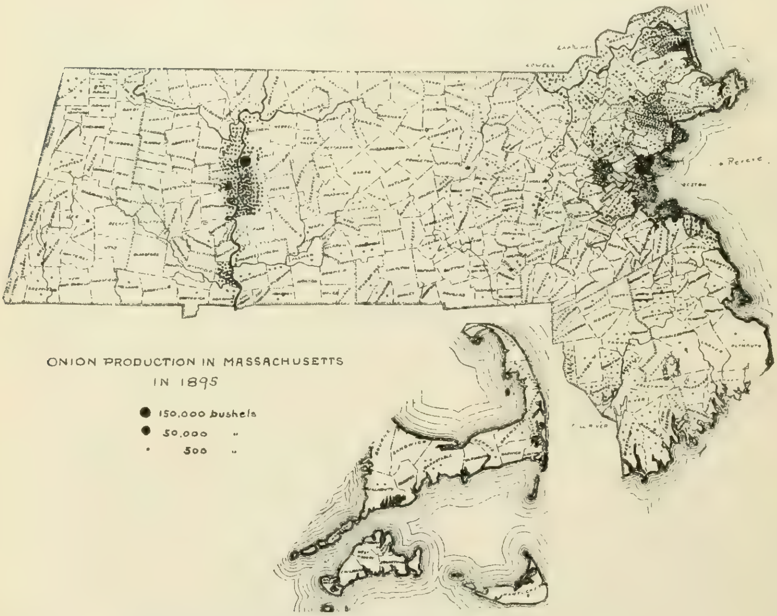


FIG. 7. — The distribution of the Massachusetts onion crop in 1895. Note the development in the Connecticut Valley, both east and west of the river.

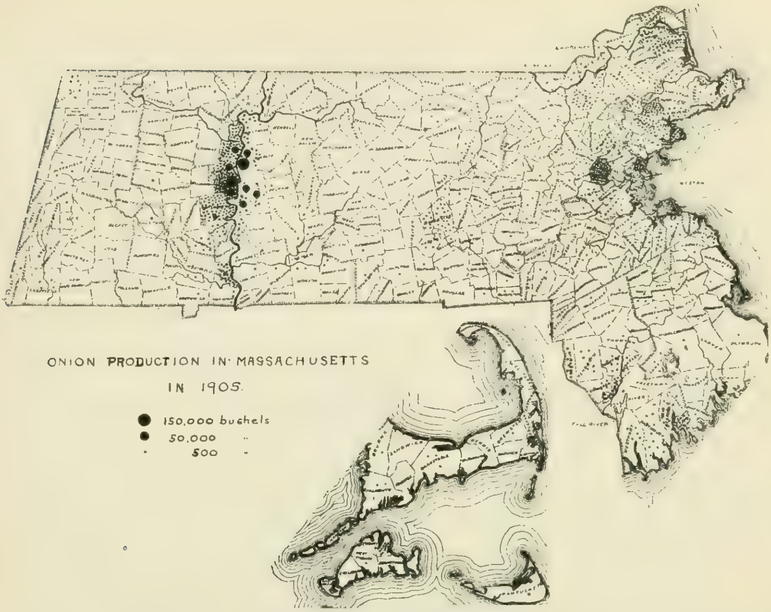
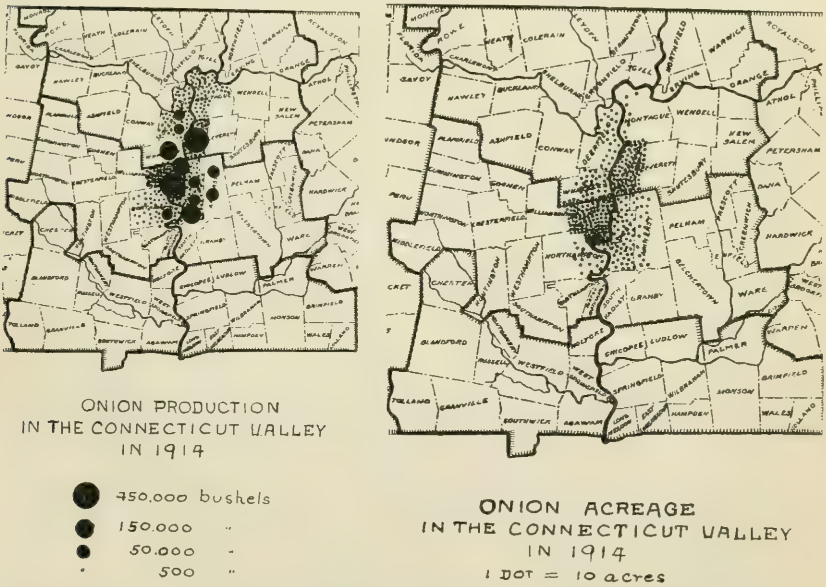


FIG. 8. — The Massachusetts crop in 1905. Note how the industry has shifted west to the Connecticut Valley.



FIGS. 9 and 10. — These maps show the relative importance of the various towns as onion-producing centers in 1914.

total onion acreage in Franklin and Hampshire counties was about 15,[1] as compared with 4,160 in 1915.

These maps show the gradual shifting of the onion-producing area from the eastern part of the State to the valley of the Connecticut River. The rapid development of the industry between 1885 and 1895 was a forecast of future commercial onion growing in Massachusetts.

The growth of the industry in the valley is shown by the diagram below.

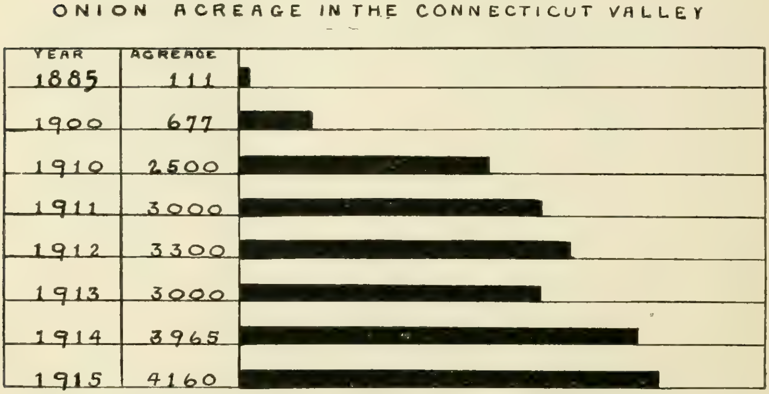


FIG. 11. — Onion acreage in the Connecticut Valley. This chart shows the development of the onion acreage in the Connecticut Valley over a period of years.

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[1] The report of the Secretary of the Commonwealth for 1855 gives the following data on the onion industry in Massachusetts: —

COUNTY.	Acres.	Bushels per Acre.	Value.
Barnstable,	34½	151⅚	$4,000 00
Berkshire,	18	289 4/9	1,351 00
Bristol,	21⅝	352⅕	4,170 50
Dukes,	¼	632	106 00
Essex,	521⅚	338½	147,136 00
Franklin,	5¾	189¾	990 25
Hampden,	14½	360¾	3,343 40
Hampshire,	8⅚	420 5/7	2,454 50
Middlesex,	42¾	260⅔	7,486 10
Nantucket,	5	187	516 00
Norfolk,	62⅚	241½	6,490 00
Plymouth,	9	313 7/10	2,066 30
Suffolk,	½	–	–
Worcester,	24½	332⅕	7,336 40
Total,	769⅞	313	$187,446 45

For Hampshire and Franklin counties the distribution by towns was as follows: —

	Acres.		Acres.
Amherst,	1	Conway,	¼
Hadley,	½	Deerfield,	½
Middlefield,	⅓	Gill,	1
Pelham,	½	Greenfield,	1
South Hadley,	5	Monroe,	¼
Ware,	½	Montague,	¼
Ashfield,	2	Northfield,	¼

Connecticut Valley Onion District.

Topographic Features of the Connecticut Valley.

The Connecticut Valley is an elongated basin extending through western Connecticut and Massachusetts. It has a slight southwestern trend, and the Connecticut River flows lengthwise through its central part. At the northern border of Massachusetts its width is about 2 miles. The eastern border extends southward in a generally straight line. The western border, however, is less regular, receding by three successive steps until the valley reaches the width of approximately 25 miles at Hartford.

Throughout the area the walls are comparatively steep and high, and notched by narrow, picturesque gorges through which the Miller and Chicopee rivers enter from the east, and the Falls, Green, Deerfield, Mill, Westfield and Northampton rivers on the west. The surface of the valley is frequently broken by long and abrupt ridges and peaks. The Mount Holyoke range extends from New Britain nearly to Northampton, and then turns east across the valley which it almost completely divides. The Deerfield range extends from Mount Sugarloaf near Sunderland to the village of Gill beyond Greenfield.

In this survey we are concerned only with that portion of the valley lying between the towns of Wendell, Gill and Greenfield on the north and Chicopee and Holyoke on the south, a strip approximately 25 miles in length, with an average width of about 5 miles. This includes the towns of Deerfield, Montague, Sunderland, Whately, Amherst, Hadley, Hatfield and Northampton, the principal onion-producing towns in western Massachusetts.

Onion Soils.

The United States Bureau of Soils recognizes at least fourteen soil types found in larger or smaller areas in the Connecticut Valley. These range in character from clays and heavy loams through fine and coarse grades of sand to gravel. The soil known as the Connecticut meadows, a dark silt loam overlying a silt and very fine sand subsoil which grows heavier downward, is the chief onion soil of the valley. Besides silt both the soil and subsoil contain a considerable quantity of very fine sand and a little clay.

Large areas of this type of soil are found along the Connecticut River at Northampton and extend northwest into Sunderland. Comparatively large areas are also found in the Deerfield Valley and near Northfield. Other important soil types found in the valley, which lend themselves to onion growing when in proper mechanical condition and well fertilized, are the Hartford very fine sandy loam and the Hartford sandy loam.

The total number of acres of cultivated, uncultivated and unimprovable land in the Connecticut Valley onion area in the census year 1905 is shown by the following table. Approximately 56 per cent. of all the

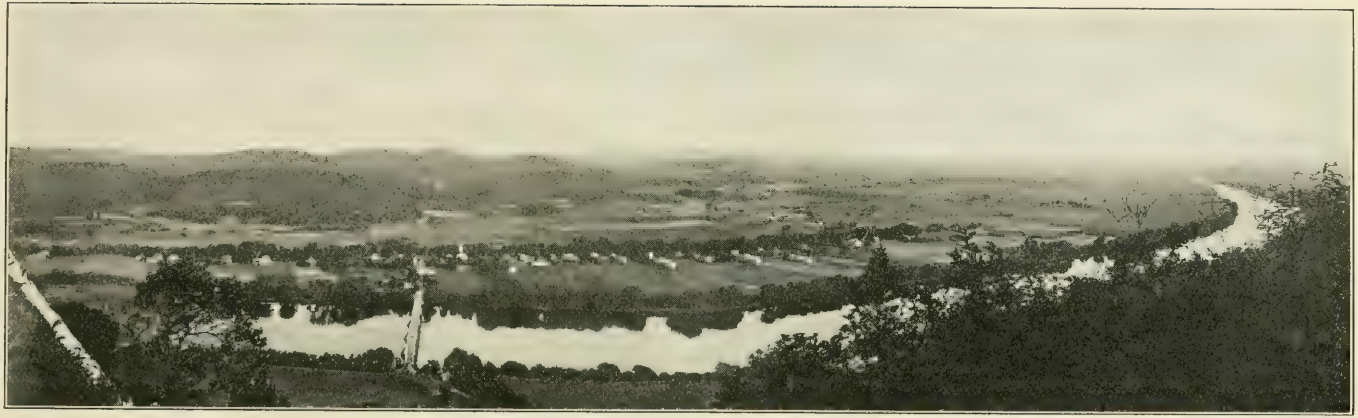

Fig. 12. — The Connecticut Valley, east of the Connecticut River, as seen from Mount Sugarloaf. Over the bridge on the left thousands of bushels of onions are hauled every season from the Sunderland farms and storages to the nearest shipping point, South Deerfield. The Sunderland Meadows, famous for onions, extend from the extreme left of the picture to the sharp bend in the river on the right.

farm land was under cultivation. In 1914 the onion acreage in this area was 3,965, or a little more than 9 per cent. of the cultivated acreage in 1905.

Cultivated, Uncultivated and Unimprovable Acreage in the Onion District of Massachusetts, from the Massachusetts Census of 1905.

Town.	Acres Cultivated.	Acres Uncultivated.	Acres Unimprovable.
Franklin County.			
Deerfield,	6,334¼	7,522¼	69
Montague,	5,461¼	5,275½	428
Sunderland,	2,911¾	1,986	60½
Whately,	3,292	4,641¼	188½
Total,	17,999¼	19,425	746
Hampshire County.			
Amherst,	6,719	5,107½	225¾
Hadley,	7,593⅝	3,069¼	177
Hatfield,	4,572½	1,015	21
Northampton,	5,268⅜	4,949	6
Total,	24,153½	14,140¾	429¾

The importance of the valley in onion production is indicated by the fact that 2,955 cars of onions, including "sets," were shipped during the season of 1913–14. In 1914–15 the shipments reached the remarkable total of 3,826 cars, or nearly 2,000,000 bushels. In 1915–16 the shipments were 3,340 cars, a decline of about 500 cars, or 250,000 bushels from the 1914 figures. Farm management surveys of 47 farms in Franklin County and 70 in Hampshire County show that on these farms in 1914 the receipts from onions constituted 31 per cent. and 23 per cent., respectively, of the farm receipts from all sources.

General Marketing Facilities.

The Connecticut Valley is fortunate in location. In close proximity to all the large markets of the North Atlantic States with which it is connected by numerous transportation lines, its shippers experience little trouble in getting their produce to market. Comparatively short hauls and direct routes make for low transportation rates and quick service. The losses in transit from the valley to primary markets for onions of standard quality are small indeed. Very few areas enjoy better general marketing facilities.

General History of Onion Growing in Massachusetts.

As late as 1885, Essex County was the center of onion production in Massachusetts. Onions have been raised in this county from colonial times, and in 1842 the first premium of $10 was offered by the Essex Agricultural Society for their production. We have evidence that one town raised onions on certain lands for eighty successive years prior to 1849. A history of the town of Danvers, — the most important onion-producing town in Essex County, — written in 1848, says that approximately 120,000 bushels of onions were raised yearly, and that "probably no town in the world raises as many onions as Danvers."

It was not until 1850 that the cultivation of onions began in the Connecticut Valley, in the town of Sunderland. From that date the acreage steadily increased, and by 1875 had spread along the river through Franklin, Hampshire and Hampden counties. By the year 1885 the supremacy of Essex County in the onion industry was seriously challenged, and from 1895 the Connecticut Valley became indisputably the onion area of Massachusetts. Until the census year 1905 the town of Sunderland maintained first position both in acreage and in production, but since that time it has been outstripped by Hatfield.

The nationality of western Massachusetts farmers has changed considerably, particularly in the onion and tobacco industries. In 1853 in the four western counties — Berkshire, Hampshire, Hampden and Franklin — foreign laborers constituted less than one-fifth of the total, and those were mostly Irish and French. In the eastern part of the State by far the larger number of hired farm laborers were foreign. In the counties of Norfolk, Middlesex and Essex more than three-fourths were foreign. The influx of Poles, Lithuanians and Slovaks, which had fairly set in by 1890, has had a direct effect on the growth of the onion and tobacco industries in the Connecticut Valley. Since that date the proportion of these races has been steadily increasing and the onion industry, which calls for a large amount of hand labor which the foreigners are willing and able to give, has grown steadily. In 1895, 16 per cent. of the foreign population in Deerfield, Sunderland, Montague, Whately, Amherst, Hadley and Hatfield were born in Poland, Austria and Russia. In 1905 the proportion had grown to 44 per cent. A seed firm doing a large business in the valley reports that its list of customers in 1895 contained the names of only two foreigners; in 1915 the total number of customers in the same territory was 198, of whom 145 were foreign born.

There has been no striking change in the methods of growing onions. In early times the seed was planted by hand; but since the introduction of onion culture along the Connecticut River the hand seeder and hand cultivator have come into use. Adaptations and improvements of these two implements have been practically the only change worth noting in the culture of the onion.

In 1916 the eight-row horse seeder made its appearance. These gang seeders are proving very satisfactory. They make possible at least eight rows that are sown alike and spaced evenly, and with the tank attachment for carrying formaldehyde solution an effective treatment for smut may be applied directly when the seed is sown.

Economics of Production. Tenure of Land.

In Franklin, Hampden and Hampshire counties, in 1910, 94 per cent. of the farms were operated by owners, 5 per cent. by cash tenants and 1 per cent. by share tenants. In the same year 93 per cent. of all Massachusetts farms were operated by owners, 6 per cent. by cash tenants and 1 per cent. by share tenants. Practically no change has occurred in this regard since 1880. In fact, Massachusetts exhibits an exceptionally high percentage of ownership.

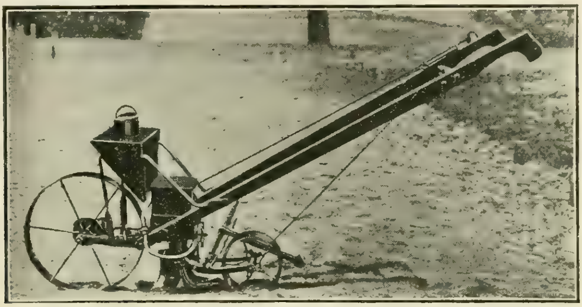

FIG. 13. — A Planet, Jr., hand seed drill. This type of seeder is widely used among Massachusetts onion growers. Note the tank for carrying formaldehyde solution.

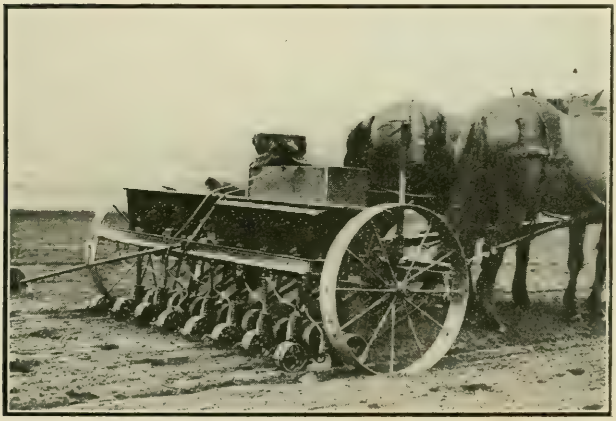

FIG. 14. — The new eight-row horse seeder. This drill is equipped with a 21-gallon tank for carrying formaldehyde solution. It was first used by Oscar Belden & Sons of Hatfield, Mass., in 1916.

The census figures on the percentage of tenancy in the Connecticut Valley are misleading when the onion crop alone is considered. In Massachusetts the proportion of tenants engaged in the growing of onions is much greater than in growing any other crop; hence, considering this industry alone, the percentage of tenants is much greater than the ratio of tenants to all farms. Most of the tenant farms are operated by immigrant families, the women and children doing much of the hand labor required for growing the crop. Very little capital is necessary to grow onions on shares, which makes this form of tenure attractive to foreigners with small means or large families.

Two general types of tenancy are found in the valley. The one may be called share rental and the other cash rental. The terms of share rental may vary widely, but the rent is usually half the crop. Under this form the owner pays for the fertilizer and frequently for half the seed, in addition to supplying all the machinery and all the labor necessary to prepare the seed bed. He also hauls his share of the onions to market. All that the renter furnishes is his share of the seed which he may buy on credit, and the labor required to grow and harvest the crop which calls for a very few inexpensive tools.

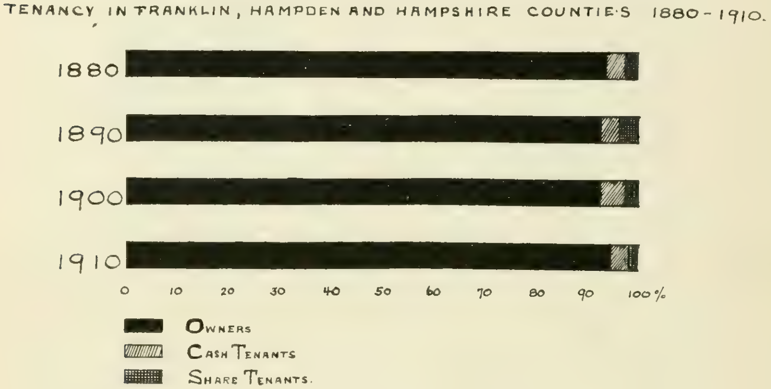

FIG. 15.

The cash rent paid for the most desirable onion land varies from $30 to $50 per acre. Under this form the landowner furnishes nothing but the land. The cash tenant requires some capital; generally, however, he experiences little difficulty in buying his seed and fertilizers on credit. By beginning as laborers and taking advantage of these forms of tenure many enterprising immigrants, especially Poles, have been able to save enough to become farm owners.

Soils and Climatic Conditions.

Onions may be grown successfully under a wide range of climatic and soil conditions. During the early stages, however, cool weather and a good deal of moisture are essential. Later, a reasonable degree of heat, together with a dry soil and atmosphere, are needed for the ripening and proper curing of the bulb. The climatic data shown in Tables I and II are illuminating.

TABLE I. — *Precipitation (in Inches).*[1]

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1889-1913 (mean),	3.47	3.28	3.99	3.01	3.74	3.22	4.34	4.17	4.07	3.69	3.20	3.59	43.76
1914,	3.72	3.36	5.52	6.59	3.56	2.32	3.53	5.11	0.52	2.09	2.62	2.89	41.83
1915,	6.52	7.02	0.12	3.99	1.20	3.00	9.13	8.28	1.37	2.89	2.20	5.86	51.58
1916,	2.56	5.27	3.97	3.69	3.21	5.34	6.85	-	-	-	-	-	-

TABLE II. — *Hours of Bright Sunshine.*[1]

	JANUARY.		FEBRUARY.		MARCH.		APRIL.		MAY.		JUNE.		JULY.		AUGUST.		SEPTEMBER.		OCTOBER.		NOVEMBER.		DECEMBER.		YEAR.	
	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.	Mean.	Mean Per Cent.
1889-1913,	137	46.6	159	53.4	189	50.9	221	55.0	224	49.5	253	55.4	260	56.3	228	53.3	197	52.9	165	48.4	122	41.4	130	45.9	2,304	51.7
1914,	95	32.0	178	60.0	170	46.0	194	48.0	324	72.0	283	62.0	241	52.0	209	49.0	246	66.0	164	48.0	113	38.0	160	57.0	2,377	53.0
1915,	144	49.0	115	39.0	290	78.0	223	56.0	273	60.0	269	58.0	191	41.0	152	35.0	181	49.0	162	48.0	118	40.0	106	38.0	2,224	50.0
1916,	140	48.0	140	47.0	217	58.0	123	31.0	181	40.0	156	34.0	184	40.0	-	-	-	-	-	-	-	-	-	-	-	-

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[1] Massachusetts Agricultural Experiment Station, Bulletin 153, and Massachusetts Meteorological Bulletins 301-331.

Frosts.[1]

YEAR.	Last Frost.	First Frost.
1913,	May 15	September 10
1914,	May 16	September 28
1915,	May 20	September 23

These tables are inserted to give the reader some idea of the climatic conditions prevalent in the Connecticut Valley. For comparative purposes the twenty-five years' mean (1889–1913) is also given. The crop year 1914 was ideal for onions, judged from the standpoint of yield and keeping quality, while 1915 was decidedly below the average in these respects. Note the departures from the normal during the growing and harvesting season, both in precipitation and sunshine.

Onions are now grown successfully in the United States on three general types of soil.

1. *Clay and Alluvial.* — These soils, though fertile, usually need a considerable amount of manure to lighten them. They are the soils of the river valleys and delta regions near the coast. Spanish and Egyptian varieties are almost exclusively grown on soils of this type.

2. *Muck and Peat.* — These are found in large areas throughout the States bordering the Great Lakes. They require considerable attention before they are suitable for onion growing. On this type are grown most of the Orange County (New York) and Ohio onions. There are still very large tracts of this soil awaiting reclamation.

3. *Sandy Loams.* — These soils, especially when overlying a well-drained subsoil as in the Connecticut Valley and with a liberal application of commercial fertilizer, are ideal for onion growing. The silt loam known as "Connecticut meadows" has a decided advantage over others in that the onions mature better, become much harder and are of better keeping quality. The onions grown on this soil are found on the market in March and April, and even as late as May.

In the Connecticut Valley the physical character of the soil determines the specific crop to be grown, and the adaptability of those soil types to such special crops has been the principal basis of land valuation for the last half-century. The principal competing crops are tobacco, corn, hay and potatoes.

There is still much land in the towns of Northampton, Amherst, Deerfield and Montague which might easily be put into condition for successful onion growing. In Hatfield, Sunderland and Whately, however, practically all the available land suitable for profitable onion growing is now devoted to the crop and very little extension of the present area is possible.

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[1] Massachusetts Agricultural Experiment Station, Bulletin 153, and Massachusetts Meteorological Bulletins 301–331.

Extent of Industry.

In 1905 (the latest statistics available) the number of growers in the valley was 850, and the number of bushels grown was 782,860, making an average production of 925 bushels per grower. Ten years before, in 1895, there were but 372 growers raising 310,309 bushels, representing 856 bushels per grower.

Methods of Culture.

Under very favorable conditions with proper fertilization, tracts of land may be continuously cropped with onions, but it seems better, and in some sections of the valley absolutely necessary, to practice some system of crop rotation. This will often prevent the land from becoming infested with disease and insect enemies.

The methods of fitting land for onions vary somewhat with the character of the soil, the locality and the season. As a rule, Connecticut Valley growers plow in the autumn, but defer it as late as possible. Fall plowing is especially desirable, because the ground can be worked earlier in the spring, and, in this section, it is necessary to get the seed and sets into the ground at the earliest possible date.

For surface fitting in the spring, a disk harrow or plow is used for breaking up the soil. This is followed by an Acme harrow or any device which will thoroughly pulverize the surface. To give the final smoothing to the soil before planting, a device called the Meeker harrow is used. This consists of four rows of small disks set in a rectangular wooden frame, two rows at either end. Across the middle of the framework is fastened a board tilted slightly from its vertical position for the purpose of smoothing the ground. The harrowing, disking, rolling and dragging are continued until the soil is smooth and mellow to a depth of 4 or 5 inches. Usually not less than a full day's labor of man and team is required to prepare an acre of onion land for seeding.

The return per acre justifies the grower in using a large quantity of high-grade fertilizer. In the Connecticut Valley where stable manure is not very plentiful growers resort almost wholly to commercial fertilizers. Some growers find it desirable to purchase the ingredients and mix their own chemicals, but the majority use ready-mixed fertilizers. No general formula can be given, because the natural character and needs of the soil, together with its previous treatment, are the only safe guides as to proportions and quantity. The average cost per ton through the valley in 1914 was $33.92, and the average application, 3,000 pounds to the acre. Successful growers advocate applying fertilizer early in the spring, so that it may be thoroughly incorporated with the soil by the various fitting operations.

Seed and Sets.

Connecticut Valley onions are propagated both from sets and from seed. Sets are small onions produced from seed thickly sown in comparatively poor soil. These small onions are planted the following spring and mature full-grown onions at least a month earlier than onions grown from seed. Owing to the cost of the sets, perhaps averaging about $56 an acre, and their setting, a comparatively small acreage is thus grown — in 1914 about 225 acres, belonging chiefly to the larger growers. Most of the onions are propagated by sowing the seed in rows in the field where the crop is to mature. Naturally, only seed with a high germinating test should be used. Over half of the seed now used in the Connecticut Valley is California-grown. A large percentage of the remainder is grown near Milford and Wethersfield, Conn.

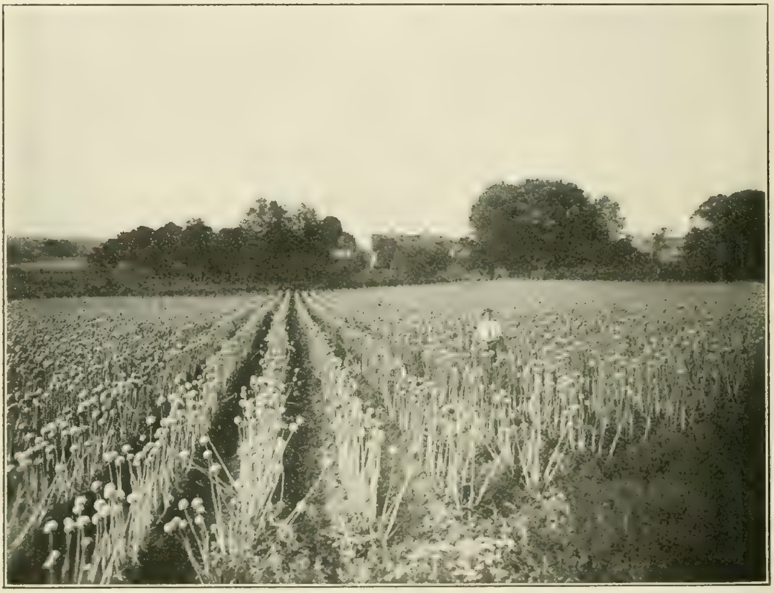

FIG. 16. — A good field of Connecticut Valley onion seed as it appears just before it is harvested. Heavy winds and hail spell ruin for this enterprise.

Very little seed has as yet been grown in the Connecticut Valley, but several demonstration plots have proved conclusively that it can be profitably raised. One prominent seed house doing business in the valley harvested from a plot of approximately 1 acre 430 pounds of marketable seed. This is about one-third to one-fourth less than the California yield under favorable soil and weather conditions. In 1915 good seed cost the grower about $1.30 per pound and $1.50 on credit. Generally from 5 to 6 pounds of seed are required to sow an acre. The seed is sown as early in the spring as the soil can be brought into proper condition, usually about the first week in April.

Varieties.

In the selection of varieties, both soil conditions and market requirements must be considered. That variety should be selected which has the greatest number of desirable characteristics, or commands the best price in the market for which it is grown.

Over 95 per cent. of the onions grown in the Connecticut Valley are of the Yellow Danvers variety. This variety, a bulb of medium size, globular in form, hard and compact in structure, with a close thin skin and a small neck, is very productive. It has excellent keeping qualities and is, therefore, well adapted for storage and shipping purposes. While it has an excellent flavor, and under existing conditions is undoubtedly the best general variety for the Connecticut Valley, it is, nevertheless, far inferior in texture, flavor and keeping quality to the Spanish and the Denia varieties.

A small acreage of the Red Wethersfield variety is also grown and good yields are reported. The bulbs are large and keep well. The skin is deep purplish-red, the flesh purplish-white, somewhat coarser and of stronger flavor than the yellow onions. This variety is preferred to Yellow Danvers in some markets, especially those patronized by the French, but in most eastern markets the price is much lower.

Weeding.

Usually the first cultivation comes about three weeks after the seed is sown, the purpose being to loosen the soil, which is always more or less packed during the seeding and by rains, and to destroy all weeds. Three to seven weedings and numerous workings with hand implements are required, depending very largely upon the condition of the land and the season. Each weeding costs from $6 to $8 per acre, according to the wages paid and the difficulty of weeding. The implements employed are the onion hoe, shove hoe, hand cultivator and weeding hook.

Economic Factors.

On an average, one man can take care of about 3 acres. This amount may be considerably increased if he is assisted by his wife and children. Growers who plant from 10 to 75 acres must necessarily employ a large force of hired men, whose time is usually distributed between the onion and tobacco crops, a number being retained throughout the year, while others are employed for the season. During the planting and harvesting additional day laborers must be hired at wages ranging (in 1915) from $1.50 to $2 per day, without board.

In growing onions the amount of land per man is relatively small. Well fertilized and cultivated, a small acreage is more profitable than a larger area only moderately well cared for. Good onion land is worth from $300 to $500 per acre, and much labor is necessarily required in growing the crop, as well as a large outlay for fertilizer; hence the necessity for a small acreage per man, intensive culture and a large yield. The outlay for equipment is a small item, because most of the labor is done by hand.

Harvesting.

The harvesting of onions from sets begins about the second or third week of July, varying somewhat with the season and the condition of the market. In 1915, for instance, when the Texas crop held on long into the summer, the harvesting of sets was delayed for fully a week awaiting a better market. Even then they were sold to dealers for 75 cents per 100 pounds, and by them in turn for 90 cents to $1 to the trade. The preceding year the conditions were just the reverse; the price was $3 to $5 per 100 pounds, causing the crop to be harvested very early and rushed onto the market.

The processes of harvesting are pulling, clipping, drying, screening and bagging. In general, the harvest season extends from about August 20 to the middle of October.

While lifting machines are used to some extent for pulling onions, by far the greater number are removed by hand. This is undoubtedly the better way, because the present type of machine is likely to cut the bulbs or to cover the roots with soil. If allowed to lie covered a few days new roots may start and render the bulb worthless.

The time for pulling onions varies to a certain extent among the growers. A good many hold that onions should not be taken from the ground until the tops have bent over by their own weight and are pretty well dried. Ripened in this way, onions are practically cured in the ground, and after their removal may be clipped and marketed or placed in storage almost immediately. There are others, however, who advocate pulling the onions while still somewhat green, in fact, just as soon as they have attained full size. Such onions, these growers believe, should be clipped as soon after pulling as possible and immediately put into storage. Under these conditions they will keep their outer skins, very seldom develop roots in storage, and with curing become solid bulbs of excellent color. All growers agree that onions must not be allowed to become too ripe before pulling on account of the tendency to take root again, especially if the season is wet.

It would seem, then, that the time of marketing should, in part, determine the proper time for pulling. If they are to go on the market immediately the onions should be allowed to get fairly ripe. After the roots have become dry they can be clipped, screened, bagged and marketed. Onions thus treated will look better and, therefore, find a more ready sale than if not so ripe or less well cured. However, onions should not be allowed to lie on the ground very long, because the hot sun and rain are liable to destroy the color, crack the outer skin and render them less salable. On the other hand, experienced storage men agree that if they are to go into storage they should be pulled rather green and allowed to cure in storage.

They may not look so well when put in, but they keep better, and the desirable color comes with curing.

The amount of work connected with harvesting a crop often makes it necessary to leave onions on the ground for several days. This will not hurt them necessarily, if they are not clipped, but clipped onions that remain on the ground overnight are likely to absorb moisture and become spongy.

A few of the growers have been cribbing their onions with very good results. This is done by putting the onions directly from the field, often without topping, into 2½-bushel crates. These crates are then placed two crates wide and four crates high in a crib similar to the ordinary corn crib, but open at the sides. They are left there until the latter part of November, and then removed into the ordinary storage. The open sides of the crib allow the wind to blow right through the onions. This dries them thoroughly, and the bulbs cure down into hard onions of excellent color. Onions cared for in this way usually sprout very little in the regular storage, and the shrinkage is considerably reduced. The objection to this method is that it is rather expensive due to the extra labor required. In a general way, it would seem that the Ohio method of crating the onions and stacking them in the field would be preferable.

Cost of Production.

The cost of raising an acre of onions in 1915, based on the best figures obtainable, and the items among which the cost is distributed, are as follows: —

COST OF PRODUCING AN ACRE OF ONIONS TO THE LANDOWNER.

Value of land,			$300 00
Rent (calculated at 5 per cent.),			$15 00
Tools, etc.: —			
Seeder,	$13 00		
Hand cultivator,	4 50		
Onion hoe,	75		
Shove hoe,	1 50		
Shovel,	1 50		
Screen,	13 50		
Baskets (2),	1 00		
Shears,	75		
Rake,	50		
		$37 00	
Horse implements: —			
Plow,	$45 00		
Disk harrow,	25 00		
Acme harrow,	12 50		
Meeker harrow,	24 00		
Fertilizer sower,	40 00		
		146 50	
Total investment in farm equipment,		$183 50	

Interest on value of equipment (calculated per acre),	$2 97
Taxes on land valuation $60, rate $18 per $1,000,	1 08
Depreciation of equipment per year (calculated per acre),	3 40
Fertilizer, 3,000 pounds at $34 per ton,	51 00
Seed, 6 pounds at $1.30 per pound,	7 80
Labor, for fitting land and sowing fertilizer: —	
11 2-horse hours at 50 cents,	5 50
4 hours' drilling in seed at $1.75 per day,	70
Labor, for tending crop: —	
21 days' weeding, 4 days' shove hoeing, 5 days' cultivating, } 30 days at $1.75,	52 50
Labor, pulling: —	
1½ days at $1.75,	2 63
Total cost per acre to landowner,	$142 58
Total cost per bushel (460 bushels per acre),	31

Cost of Producing an Acre of Onions to the Cash Tenant.

Land rental (average),		$38 00
Tools, etc.: —		
Seeder,	$13 00	
Hand cultivator,	4 50	
Onion hoe,	75	
Shove hoe,	1 50	
Shovel,	1 50	
Screen,	13 50	
Baskets (2),	1 00	
Shears,	75	
Rake,	50	
	$37 00	
Interest and depreciation on investment in tools (calculated),		2 10
Fertilizer, 3,000 pounds at $34 per ton,		51 00
Seed, 6 pounds at $1.45 per pound (credit),		8 70
Labor, for fitting land and sowing the fertilizer: —		
11 2-horse hours at 50 cents,		5 50
4 hours' drilling in seed at $1.75 per day,		70
Labor, for tending crop: —		
21 days' weeding, 5 days' cultivating, 4 days' shove hoeing, } 30 days at $1.75,		52 50
Labor, pulling: —		
1½ days at $1.75,		2 63
Total cost per acre to renter,		$161 13
Total cost per bushel (460 bushels per acre),		35

Yields.

Despite rather striking variations by years, the average yield per acre of Connecticut Valley onions has measurably increased in recent years, due to better farm practices and effective control of some onion diseases.

In 1913, on 3,849 acres planted, the average yield per acre was 336 bushels; in 1914 the average yield per acre was 460 bushels, with an acreage of 3,965. This was the highest average reported by the Bureau of Crop Estimates for the 12 States of surplus production. In 1914 the average yield of 86 growers scattered through Franklin and Hampshire counties was 520 bushels per acre.

Of the 86 growers, from whom data were obtained by personal interview in 1914, 27 growers in Sunderland reported an average yield per acre of 572 bushels; 5 growers in Whately, 398 bushels; 5 in Deerfield, 248 bushels; 6 in South Deerfield, 317 bushels; 21 in Hatfield, 600 bushels; 11 in Hadley, 521 bushels; and 11 in Amherst, 485 bushels per acre.

The following table presents the figures obtained from the 86 growers who were personally interviewed by representatives of the college: —

TOWN.	Number of Growers.	Total Acreage.	Total Production.	Average Yield per Acre (Bushels).
Sunderland,	27	315.75	180,575	572.0
Whately,	5	50.75	20,200	398.0
Deerfield,	5	58.00	14,396	248.0
South Deerfield,	6	53.00	16,776	316.5
Hatfield,	21	234.33	140,707	600.0
Hadley,	11	42.50	22,143	521.0
Amherst,	11	79.75	38,640	485.0
Total and average,	86	834.08	433,437	520

PART II.

MARKETING THE CROP.

Preparation for Market.

The onions of the Connecticut Valley are marketed as sets and as seed onions. These are graded into *picklers* and *primes*, the latter including all bulbs exceeding 1⅜ inches in diameter.

Topping and Curing.

Very little attention is given to the curing of onions grown from sets. When the season is at its height, it is not uncommon for onions that are pulled in the morning to be in the cars on the way to market by evening, it being necessary only to dry the roots a little. The late or seed onions, however, especially if they are not put into storage, are allowed to lie on the ground usually in windrows for a period varying from a few days to two weeks before topping. There is danger from too much exposure to sunshine; hence the bulbs are stirred frequently with wooden rakes, but even then some injury to color, outer skin and quality results.

Most of the onions are topped or clipped in the field with ordinary sheep shears. Topping machines are sometimes employed, the onions being hauled from the field to the storage and there run through the topper either immediately or when they are removed from storage in the winter. These machines remove the tops, grade the bulbs and deliver them into crates or bags. Unclipped onions take up a little more room, but storage men usually agree that they keep as well if not better than topped onions.

Screening and Grading.

When the topped onions are thoroughly dry they are cleaned and graded by screening them. This is done in the field, and for efficient work with a medium acreage eight or nine men are required. The men are distributed as follows: two shovel the onions into bushel baskets; two carry them and dump them on the screener; two shake the screener; one takes off the bags; one weighs them; and another sews the bags up. When the onions are screened for storage, the last two men are not needed.

The screen, which has come into use within the last ten years, has a sloping bed of slats with 1⅜-inch openings, and sides 6 to 8 inches high. The distance between the slats was at first 1½ inches; a few years later it was reduced to 1⅜ inches; and about two years ago by some farmers to 1¼ inches. This opening should not be made smaller. Practically all contracts made between grower and dealer call for onions screened over $1\frac{3}{8}$-inch screens.

The onions that pass through the screen are called *picklers*. Those that pass over the screen are caught in bags and crates and sold as *primes*. The picklers are frequently rescreened over a small screen to free them from dirt and the very small onions.

Since screening is the only means of cleaning and grading onions shipped to the market directly from the field, too much care cannot well be exercised by the grower in this operation. The men who operate the screen should be given time sufficient to pick out the dirt and poor onions. Overloading the screen and failure to keep the openings free from dirt and onions are practices entirely too common among growers.

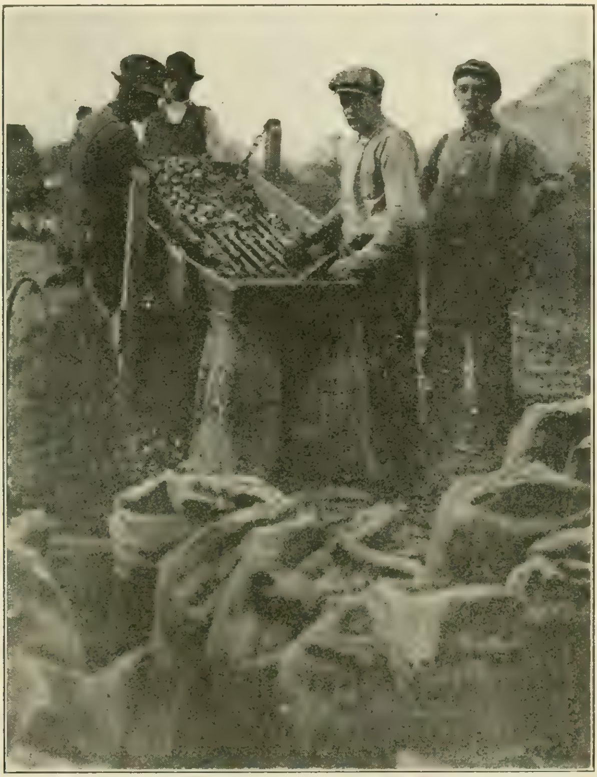

FIG. 17. — Screening onions in the field. Note how it delivers primes into the sacks. Carefully screened onions help the Connecticut Valley onion trade; poorly screened onions damage it.

Practically all the buyers and storage men of the Connecticut Valley agree that a third or intermediate grade, although unnecessary for the present demands of the trade, might be made with profit. This is also the view held by the commission men and wholesale dealers of the Boston market. All distributors find fault with the grading done by the farmers. Onions are frequently graded so poorly that it becomes necessary to rescreen an entire consignment to bring it up to the standard. This, of course, entails much additional expense, and is one reason why some farmers find it difficult to sell their product at the best prices. *Careful grading is not only desirable, but it pays.* Again, whether onions are shipped immediately or placed in storage, they should be perfectly dry when put into the bags or crates.

Labor required to prepare Onions for Market.

One man can top by hand from 50 to 70 bushels of onions per day. Men who do this work receive $1.75 per day, or by piece work 4 cents a bushel. Unclipped onions usually sell for 4 cents less per bushel than the quoted price. A gang of eight or nine men will screen and bag from 1,000 to 1,200 bushels in a day. These men receive $1.75 per day, without board, or, if employed by the month, from $35 to $45, without board, making the cost of screening and bagging approximately 1.7 cents per bushel.

Hauling.

The average initial haul from field to car or to storage is approximately 2½ miles. The average 2-horse load contains from 60 to 65 bags of 100 pounds each, so that a car of 500 bushels may be filled in a day by making four trips. For a team and driver farmers pay $5 per day; for the use of their own teams they should allow not less than $4 a day. This makes the cost of hauling to the car or storage about 1.1 cents per bushel. Thus, the average cost of preparing a bushel of onions for market and putting it into the car or storage is about 6.8 cents, distributed as follows: —

Topping,	$0 040
Screening,	017
Hauling,	011
	$0 068

Adding 31 cents, or the cost of producing a bushel of onions, gives a total of 37.8 cents, the cost delivered at storage or depot.

The small grower, with the assistance of his family, usually does all the work required to prepare his onions for market, while the larger grower employs outside labor almost entirely.

Containers for Handling and Shipping.

To move onions in the field before screening, both bushel baskets and crates are used. The cost of the baskets is 50 cents apiece, and their life, with reasonable care, four years. Crates largely used for storage hold approximately 2 bushels, and cost from 25 to 30 cents apiece. Their life is from fifteen to twenty years.

For shipping purposes bags holding 100 pounds of onions are universally employed because they furnish protection and ventilation sufficient for short hauls. They are of convenient size for marketing and cheaper than crates. Several dealers have tried crates holding approximately a bushel of onions. These crates cost from 15 to 16 cents apiece, and much extra labor is necessary for filling and handling them. The trade was unwilling to pay for the additional expense and crates were given up.

Bags are usually furnished by the buyer. Three kinds are used by Connecticut Valley shippers, as follows: —

1. *Burlap or Cotton Meal Bags.* — The cost of these in 1915 was 8 cents, secondhand, 6 cents. Their use, however, is largely confined to the farm; that is, to the moving of onions from field to storage. On account of their close weave and unattractive appearance they are not suitable or practical for shipping onions intended for sale in the original package.

2. *Grass Sacks, originally Coffee Sacks.* — These are strong and, on account of their coarse mesh which allows the onions to show through, make a very attractive container. They also permit a rather free circulation of air, and make it possible for the prospective buyer to inspect the contents without opening the bag. The cost of these bags in 1915 was 10 to 11 cents apiece. This type of bag gives character to a shipment, and is very satisfactory both to wholesaler and retailer.

3. *Woven Paper Bags.* — While these have the same general characteristics as the grass bags they are cleaner looking and make a more attractive package. They are made in Buffalo and Cleveland, and cost 10 cents apiece. The only objection to them is their lack of strength when damp. A few bruised or rotten onions in contact with the bag frequently cause it to break.

Bags are never returned directly and are, therefore, a very real expense to the local dealer and to the farmer who ships his own onions. The secondhand bags which are used come back from retailer to ragman, to assembler, to jobber, to local dealer.

Methods of Sale.

A farmer either sells his onions directly from the field or holds them in storage for later sale. In either case, since comparatively few sales are made directly from producer to consumer, he is forced to market by making use of the present machinery for wholesale distribution.

The middlemen to or through whom growers can sell directly may be summarized as follows: local country buyers, local dealers and storage men, traveling buyers, brokers and commission men. They perform with more or less efficiency one or more of several necessary distributing services: (1) collecting, gathering or assembling lots of onions, (2) grading, sorting and bagging, (3) storing for later sale, (4) transporting for long or short distances, (5) making sales to other distributors or to consumers, and finding buyers and sellers, (6) financing either growers or distributors for short or long periods by credits or advances.

Local country buyers buy from the farmers in carload lots or assemble smaller lots, and ship to the best available markets, selling on orders or through the usual market channels for whatever margin they can secure. They pay cash at the shipping point at the time of sale or delivery, and often sell on ten to thirty days' credit. They usually buy for immediate resale, but if market conditions are not satisfactory they rent storage for a short period only. These country buyers are permanently located in the community and have reputations to uphold in order to obtain business. In addition to buying onions many of them also sell fertilizers.

Local Dealers and Storage Men.

These are easily the most important distributing specialists for Connecticut Valley onions; eight of them handle at present no less than 75 per cent. of the entire output of the valley. They differ from the so-called country buyer in that they are at the same time growers, dealers and storage men. Being residents of the community, they know and are known by the farmers. They pay taxes, initiate community projects and in every way share in the life and well-being of the community.

As a class, they generally stand back of their contracts, and are respected and admired for their businesslike methods of facilitating onion distribution. Whatever may be said of some individual dealers, it is quite certain that farmers have received better prices over a period of years because of the presence of these primary distributing agents. They follow the market, standardize the product and push the Connecticut Valley onion into all the principal markets of the Atlantic seaboard States. This class of middlemen clearly can perform a very real service to the growers; knowing the requirements and the needs of the market, their advice should help materially in producing more and better onions, in putting up for market a standardized, well-graded product, and in preparing an honest, attractive, uniform pack that will top the market and stimulate the demand for valley onions.

They have a good reputation with the commission men and wholesale dealers, most of whom prefer to buy from them rather than directly from the farmers. Unless the present system of distribution is radically reorganized efficiency in distributing Connecticut Valley onions will continue to rest very largely with this class of men.

Abuses by Local Dealers and Storage Men.

One charge made against dealers of this type is that they sometimes misrepresent the actual condition of the market in order to buy at better prices — they make the farmer a victim of sharp practice. Another is that they effect a combination in such a manner as to remove actual competition in buying from the growers. In other words, there is a feeling that prices are fixed by a few who gain a monopoly. This, of course, would result in the producer not getting his rightful share of a profit which the condition of the market warrants.

On the other hand, the dealers assert that some mutual agreement is necessary for self-protection against the more or less flagrant irregularities in grading and packing. However that may be, it is certain that consistent, honest practice on the part of the farmer would remove a part at least of the reasons for the alleged combination of dealers.

Still another charge is that when the crop is large, and the market rather unsteady, dealers often refuse to buy onions excepting at under-the-market prices and in small quantities, so that they are practically insured against loss. On the other hand, if the crop is short and the market steady, they are quite willing to buy freely because there is small risk. Certainly, they are in a position to know the market, and it is their duty as dealers to share their profits, or share with the farmer his risks or losses during a year of excessive production. Otherwise, the charge of selfishness is certainly well founded.

Fortunately, however, these practices are not common; many of them arise from misunderstandings, or the trouble may be traceable to the grower himself. The fact that the dealer knows the market and its demands, whereas the grower does not, causes the latter to be suspicious of anything which does not appear perfectly plain. Anything, therefore, which will give the grower a more definite knowledge of markets will do much toward bringing about a better feeling between him and the dealer.

Traveling Buyers and Brokers.

Traveling buyers and brokers operating in the valley work along lines similar to those of the local buyer. The broker buys in quantities desired and ships to wholesale houses which have placed orders with him. For his service he charges a definite brokerage, usually about $6 per car. In addition to buying on orders he also sells for growers and shippers. Carload lots are billed directly to him in the markets and, acting as the representative of the shippers, he effects sales subject to inspection merely upon identification of shipment.

The broker handles no funds, and his brokerage is fixed regardless of the selling price of the onions. He should prevent unwarranted rejections or secure proper allowances where rejection is justified. In practice, however, brokers frequently favor buyers in order to keep in good standing with the trade. They sometimes accept orders for more cars than the trade demands, simply to get the brokerage with resulting low prices to shippers. In late years their operations in the valley have hampered the storage men in getting the maximum price for their onions.

Traveling buyers are employed by individual wholesale or commission houses on a definite salary basis, and perform the services of brokers for these houses alone. The traveling buyer purchases from both growers and dealers, and thus by becoming an actual competitor of the local dealer increases the possibility of higher prices. When a short crop is reported in the commercial onion belt, a great many of these buyers flock to the Connecticut Valley. These men have less at stake than the local dealer and are often less responsible financially. Sales should not be made to representatives of unknown firms until their business responsibility and the accredited standing of the representatives have been carefully investigated. In late years these traveling buyers have purchased largely through the local dealers, chiefly because they then have some guarantee that the onions will be fairly well graded; they are also protected against the possibility of losing onions made unfit by lax and faulty preparation for market.

Commission Men.

The commission men are dealers who receive shipments or consignments and remit the proceeds to the shipper after deducting a specified commission for selling, which for onions is usually 8 per cent. of the selling price. Some commission men, however, take 10 cents a bag commission; others ask $50 per car. In New York the rate of commission is usually less because of the larger market. Very few distributors of onions are commission men pure and simple. Ordinarily they combine the functions of jobbers and car-lot wholesalers with those of commission men. Three or four commission men in the Boston market specialize in Connecticut Valley onions.

In recent years there has been a decided falling off in the straight commission business, dealers and farmers preferring the more businesslike method of selling outright, either at the point of origin or at the destination. In cases where for any reason shipments are refused, commission men are frequently called into service.

Occasionally, agreements are made between the local dealer or shipper and a market representative, generally a commission man, for the purchase of onions on joint account. In such cases the latter contributes his knowledge of marketing conditions, and the former his knowledge of conditions at the producing end. Such agreements have been made frequently between certain large dealers in the valley and big commission firms in Boston. The division of expenses and profits varies greatly in different contracts, but the usual method is to divide net profits between shipper and market representative.

Sales for Immediate Shipment.

All onions from sets are sold from the field for immediate shipment. They are intended to supply the market after the Texas crop is gone and until the seed onions are harvested. When these appear, generally the latter part of August, sets should be entirely cleaned up.

A very large percentage of the seed onions of the valley is sold for immediate shipment. Such sales are made from the opening of the harvesting season until the first week in November. The exact quantity by weeks for three seasons is shown in the chart of shipments (Fig. 28). In nearly all cases the bags are furnished by the buyer.

The advantages of selling directly are obvious. The farmer gets immediate returns for his crop, loses nothing by shrinkage and handles it only once. He assumes no risk of the keeping quality of the product and possible injury through extreme weather. He frequently gets pretty fair prices in the fall because of the competition among buyers, all of whom are desirous of securing their needful share. This is especially true when the crop is a short one either in the valley or the commercial onion-growing belt. At such times the grower often reaps the benefit of what may be termed a "fictitious local market," which is brought about by the speculators who boost the market higher than general market conditions warrant for the purpose of securing onions for storage in anticipation of a future profit which may or may not be realized. The dullest market usually comes in October after the first rush is over and the local dealers have secured the full quota for their storages.

Comparatively few onions are now consigned by small farmers directly to commission men. Sales made in this way are for the most part limited to transactions between growers who happen to know certain commission men and consign to them a portion of their own and occasionally a neighbor's crop. The reason for the decline in such sales is due, in large part, to the fact that the farmer prefers to sell for cash, to assume no risk in price fluctuations, and no quality or quantity losses; moreover, he prefers to sell to dealers with whom he can make terms in person.

The sales to local country buyers, traveling buyers, local dealers and commission men for immediate shipment vary considerably from season to season, depending upon the strength of the market and the size of the crop. In 1913 the shipments to November 4 amounted to 1,423 cars, or approximately 50 per cent. of the total shipments for the season. In 1914 the shipments to the same date were 2,277 cars, constituting about 60 per cent. of the total shipments for the season. In 1915 the shipments were 1,730 cars, or 52 per cent. of the crop.

An analysis of the total shipments for the season 1913–14 at one of the leading shipping points shows the following facts: —

Total number of cars shipped,	1,122
Cars shipped by 4 local dealers,	947
Cars shipped by all the local buyers and dealers,	1,077
Cars shipped by farmers interested only in marketing their own product,	49
Cars shipped by Boston dealers,	6

A similar analysis of the shipments for the season of 1914–15 at the same station shows that up to November 1, 4 local dealers shipped 477 cars; all dealers and buyers shipped 624 cars; and farmers shipped 75 cars.

From November 1, 1914, to the end of the season, practically all storage onions, 4 dealers shipped 541 cars; all dealers and buyers shipped 663 cars; and farmers shipped 57 cars.

Sales from Field to Local Storage.

A great many of the onions purchased in the field by local dealers are put into storage. Such sales are usually consummated early, often before the onions are out of the ground. Onions for storage are selected on the basis of size, general appearance and keeping quality, and it is not uncommon for the storage men to stipulate the conditions of harvesting, curing and delivery of such onions. If, on delivery, the onions are not all up to the standard required, the poorer are screened out and marketed immediately and the rest stored. Onions that will store well always sell readily, frequently at a special price.

The quantity stored naturally varies from year to year, according to the crop and the conditions of the market. The local dealers who store are almost without exception also growers; hence, they may store a large portion of their own onions, and consequently buy fewer from other growers for this purpose. They may sell their own directly and store those purchased from others. In 1914–15, of the 673,900 bushels held in local and terminal storages, approximately 300,000 bushels were purchased from the growers for storing; of the remainder, 111,200 bushels were raised by the storage men themselves; the remaining 276,400 bushels were taken care of by hiring storage space either in the valley or at Boston.

Sales after Storage.

1. *By the Farmer.* — The onions stored by the farmer for later sale may be held (*a*) in temporary storages (tobacco shed, barns or cellars); (*b*) in his own private warehouse; (*c*) in a commercial storage where he rents space at a fixed price per bag or crate.

If held in temporary storages, onions are sold usually before Thanksgiving Day; if held in a private warehouse or commercial storage they are sometimes shipped by the grower himself at periods when market conditions appear most favorable. Many of the farmers' holdings in commercial storages are sold directly to or through the owner of the storage or some other local dealer.

The quantity of onions thus held varies greatly from year to year. If the season is a short one buyers are anxious and prices are high. Such conditions usually induce the farmer to sell and thus escape storage charges and probable loss by shrinkage. On the other hand, when the acreage is large and the yield heavy, prices are usually unsatisfactory and buyers hold off. At such times, farmers store for later sale and better prices.

2. *By Dealers.* — Storage men do not as a rule begin to ship before the first of December. In 1915–16 the number of bushels shipped from the first of December to the end of the season was approximately 670,000; in 1914–15, 585,000 bushels; and in 1913–14, 582,000 bushels. Practically 90 per cent. of these were shipped by local storage men and dealers. These shipments go to commission men, jobbers, wholesale distributors and retailers in practically all of the principal markets of the Atlantic States

and Canada. A few are consigned to Havana, and some years a large quantity is exported.[1]

The general problem of the local dealer in the distribution of onions may be stated thus: to keep in touch with general market conditions in all of the principal markets; to buy intelligently; to ship as the market demands; and to keep up the standard of his product without heavy losses from shrinkage. In short, he must know onions, onion growers, current market conditions, transportation and storage requirements, the needs of the market, and the marketing machinery available for wholesale distribution.

Storage of Onions.

Methods of Storage.

Onions are stored by farmers either in temporary or permanent storages. Temporary storages are barns, tobacco sheds or cellars. By covering the onions with hay or fodder they can easily be kept until Thanksgiving. After this date very few onions remain in temporary storages.

Only twelve permanent farm storages were found in the course of this investigation. Their total capacity is approximately 35,000 bushels, and in practically every instance the owners found it necessary to buy additional onions to fill them. Such men are in a sense local dealers or speculators. In 1914 the total quantity held in both temporary and permanent farm storages was about 250,000 bushels.

The cut below shows an excellent type of storage for the farm. This building follows refrigerator construction throughout, having three 4-inch dead-air spaces in the side walls. The ventilators are easily worked, and the storage is thus kept cool and dry. The shrinkage record of this particular storage is very low, and onions have been held in it from October until the end of April.

The capacity is 5,000 bushels, and the cost including equipment is approximately $1,400. The overhead charges are about four cents per bushel, distributed as follows: —

Interest on investment, $1,400 at 5 per cent.,	$70 00
Insurance at $1.25 per $100,	17 50
Taxes, $700 at $18 per $1,000,	12 60
Repairs, 1 per cent.,	14 00
Depreciation, 4 per cent.,	56 00
Care, etc.,	5 00
Insurance on onions at 40 cents per bushel at $1.25 per $100,	25 00
	$200 10
Cost per bushel (5,000 bushels capacity) approximately,	04

The cost of removing from storage is about 2.5 cents per bushel, making the entire cost of storage 6.5 cents per bushel. This includes no allowance for shrinkage, which in the particular storage is said to average not more than 2 per cent., or approximately 100 bushels for the season.

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[1] For the primary destination of onion shipments from the valley, see table of primary distributing points for Connecticut Valley onions, p. 103.

Hired Storage.

A number of the growers, as well as some of the dealers, who do not own their storages, rent space in the various commercial storages of the valley for a portion of their product. In 1914–15 the quantity so held exceeded 250,000 bushels. When the crop is heavy and fall prices are low the demand for space in these commercial storages is very great.

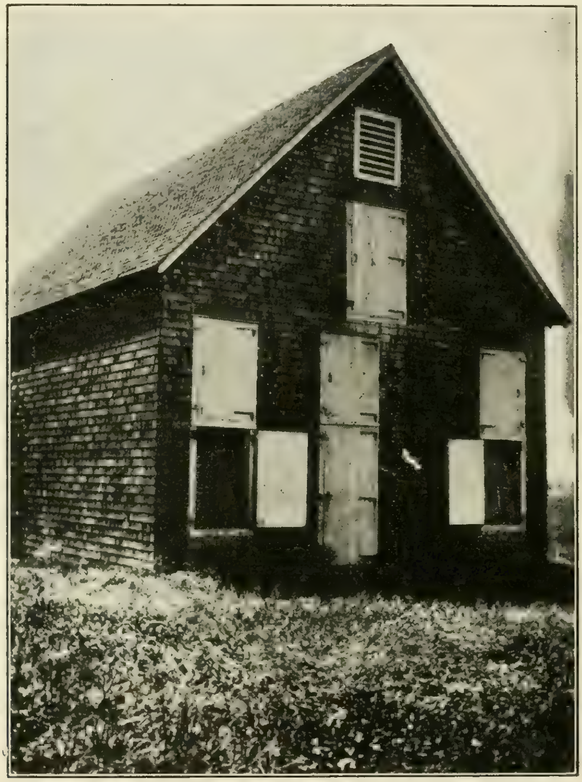


Fig. 18. — A good type of farm storage. The ventilators are well placed. Such storages yield good returns and should be found in greater number throughout the valley. The storage faces east.

If space only is rented, in which case the farmer does all the work of storing, the rate for the season is 14 cents per bag or crate. The more general method, however, is for the owner of the storage to do all the work after the onions have been delivered at the warehouse. This includes rescreening, bagging and loading on cars for final shipment. The rates charged under this form of rental are as follows: —

For less than 5 carloads,	25 cents per 100 pounds
For 5 to 10 carloads,	24 cents per 100 pounds
For 10 carloads up,	23 cents per 100 pounds

At these rates the grower simply delivers to the storage and, as noted above, all subsequent charges including insurance are borne by the storage man.

Onions are put into storage during September and October, and are generally sold before March; indeed, in order to avoid excessive loss by shrinkage, a good many are sold before Christmas.

Hired storage holdings may be shipped directly by the growers, but very frequently they are sold to or through the local dealer. When a dealer buys onions out of storage he pays for the number of bushels they will screen, which means, of course, that the grower has to bear the loss due to shrinkage. On the other hand, the storage charges are figured on the basis of the number of bushels delivered to the storage, and no account is taken of the length of the storage period.

Storage by Local Corporations or Dealers.

There are about thirty storages in the Connecticut Valley; including two built in 1915, they have a total capacity of approximately 600,000 bushels. They are fairly well distributed throughout the valley, as shown by the accompanying map. With the exception of Whately, each town has at least three storages. In 1915 the number of commercial and private storages, together with their joint capacity in each town, was as follows: —

Town.	Storages.	Commercial.	Farm.	Capacity (Bushels).
Amherst,	3	1	2	32,400
Hadley,	5	4	1	119,500
Deerfield,	8	4	4	139,000
Hatfield,	4	3	1	158,500
Sunderland,	12	8	4	142,000
Totals,	32	20	12	591,400

With the exception of a few storages owned by local storage corporations all the warehouses are located on farms some distance from the railroad. In the case of the principal storages, however, this distance does not exceed 2¼ miles.

Storage Men.

With the growth of the onion industry in the Connecticut Valley the storage men developed in a very natural way. At first they were large growers who held their onions for better prices. Very soon, however, they also bought the product of others and held it. With larger quantities in their possession and a better knowledge of markets and marketing machinery, speculation and storing became their regular business.

Even to-day there are few exclusively storage men; they are at the same time growers and dealers. They raise onions on their own farms, buy from other farmers for immediate resale, and store such portion of their own onions and purchases as general market conditions may warrant.

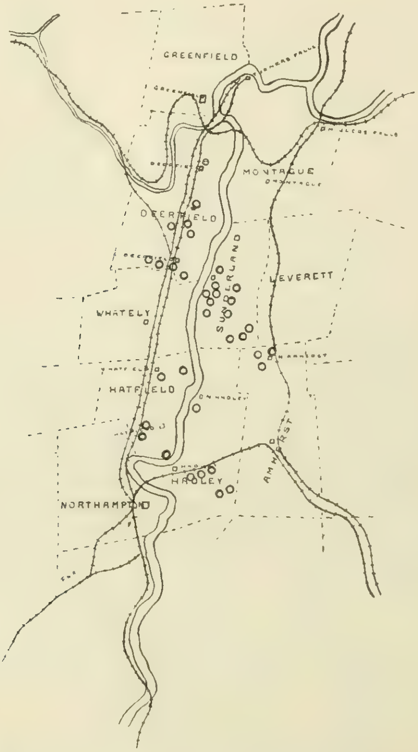


FIG. 19. — Map showing the location of the principal onion storage houses of the Connecticut Valley in 1915.

The owners of the various storages and the managers of local storage corporations are men well known in the valley, and farmers both large and small sell to them directly.

Description of Storage Equipment.

The storages are equipped with crates or bins, or both. In a few warehouses bags are still used for storing.

1. *Crates.* — The slatted crate is used almost exclusively for the storage of onions. It holds approximately 2 bushels, and permits of free circulation of air. Well-made crates now cost 25 to 30 cents apiece, and with average care last at least fifteen years. In the storage the first tier of crates is placed on "two-by-fours" to allow the air to circulate under them. Crates are scantily filled, so that when stacked one on top of another,

there is at least an inch of air space between the onions in one crate and the bottom of the crate above.

To facilitate handling there is a central alley running lengthwise through the building. A derrick for lifting the crates is operated in this alley. Cross alleys running from one pair of ventilators to the opposite pair provide for the free circulation of air.

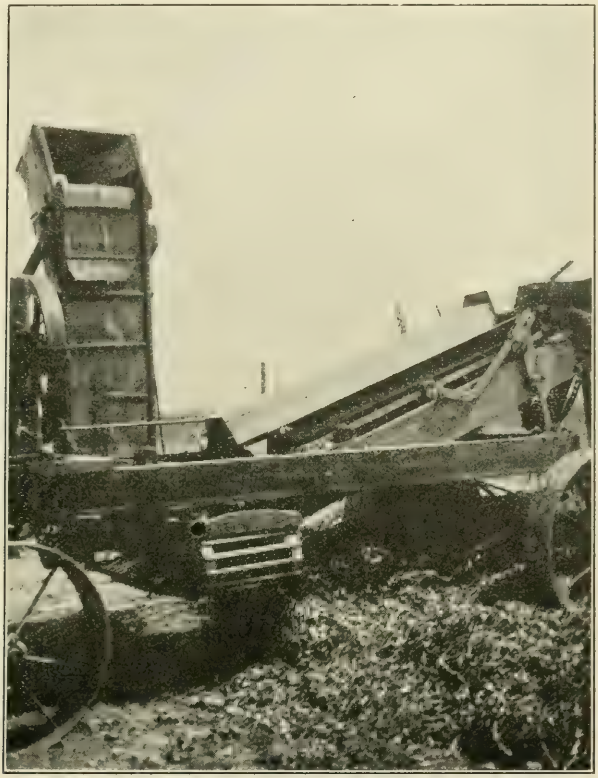


FIG. 20. — Onion topping machine. This machine is now used by six or seven of the leading onion growers in the valley. Its capacity is from 600 to 1,000 bushels per day. The elevator which carries the topped onions into the bags is lowered to a horizontal position when the machine is at work.

2. *Bins.* — Bins for storage are usually 8 feet wide and 15 feet deep, having portable shelves which slide into position on supports at each side. On this shelving onions are placed from 6 to 8 inches deep, allowing a 2-inch space for air circulation above each shelf. This is the cheapest method of storing as far as labor is concerned, and the up-keep is also small. Considerable attention, however, must be paid to the upper tier of bins, because the heat seems to affect onions stored in this way more than those stored in crates. They grow and rot much more quickly.

In order to avoid excessive loss, it frequently becomes necessary to market the onions in the upper bins very early in the season. A few storages are equipped with bins holding from 50 to 80 bushels, and having a depth of about 18 inches.

3. *Bags or Sacks.* — Formerly a great many onions were stored in bags. A few storage men in the valley still use them, placing the bags two or three deep on shelves, thereby saving much time and labor of extra handling. In years when onions are not of the best quality and the outside skin comes off easily bags are very satisfactory. As a rule, however, dealers agree that the shrinkage is greater, and that onions so stored discolor the bag and make it unsuitable for shipping. Some onions, especially those intended for early shipment, are stored in this way in practically every storage.

Dates and Periods of Storage.

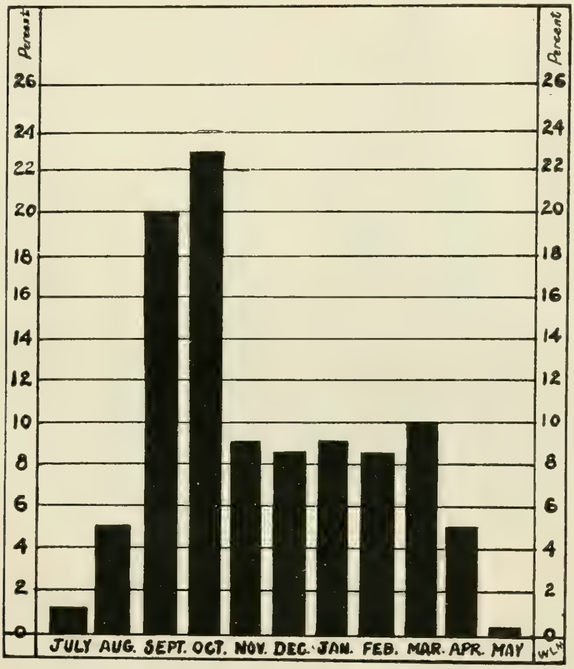
The major portion of the storage onions are placed in storage during the month of October. By the end of November shipments from field and from temporary storehouses have ceased, transactions thereafter being entirely with storage onions. For two months loss by shrinkage is comparatively small and accordingly shipments are light. In December storage onions begin to move and by the end of March practically all are marketed. These periods vary somewhat from year to year with the keeping quality of the crop and the market price but, as a general rule, as soon as there is danger of loss from shrinkage or other cause the storage men begin to unload. It will be noted from the accompanying diagram that a little over two-thirds (68.5 per cent.) of the 1914 crop was marketed directly from the field or temporary storage from July to December. One-third (31.5 per cent.) of the crop was put into permanent storage. The shipments for December constituted only 3 per cent. of the crop, but during January, February and March 25 per cent. of the total crop was marketed. On March 31 only 3.5 per cent. remained in local storages. Some years when the demand is strong and the quality of the onions good a considerable quantity is removed to cold storage about March 1.

March is the period of greatest activity. In the 1913–14 season, considering merely that portion of the crop stored, 26.6 per cent. of the onions were moved out during March; 21.2 per cent. in February; 21.9 per cent. in January. In other words, practically 70 per cent. of the storage onions were shipped to market during those three months. In the season of 1914–15 nearly 80 per cent. of the crop stored was marketed during the same period. March was again the month of heaviest shipment with 35.4 per cent.; February with 25.4 per cent.; and January with 18.9 per cent. of the stored onions.

Of the 1915 crop 59.7 per cent. was shipped from July to December. The shipments out of storage by months follows: —

Month.	Number of Cars.	Percentage of Entire Crop.
December,	272	8.1
January,	245	7.3
February,	255	7.6
March,	466	14.0
April,	107	3.2
May,	3	.1

Taking the 40.3 per cent. held in storage, 34.7 per cent. of them were shipped in March, 18.8 per cent. in February and 18.1 per cent. in January.



CONNECTICUT VALLEY ONION SHIPMENTS

FROM LOCAL POINTS 1913-14.

Fig. 21. — Note the uniformity of the shipments from November to April.

The maximum length of time onions are held in local storage is eight months; the minimum about one month; while the average period of storage is approximately three months.

The monthly shipments out of storage during 1913–14 show a remarkable uniformity. This was due in part to the short season and the fact that practically all storage holdings were in the hands of local dealers. It was a good year for them. The market was steady and the demand constant. The shipments from the valley were equally constant and helped very materially to maintain a firm market.

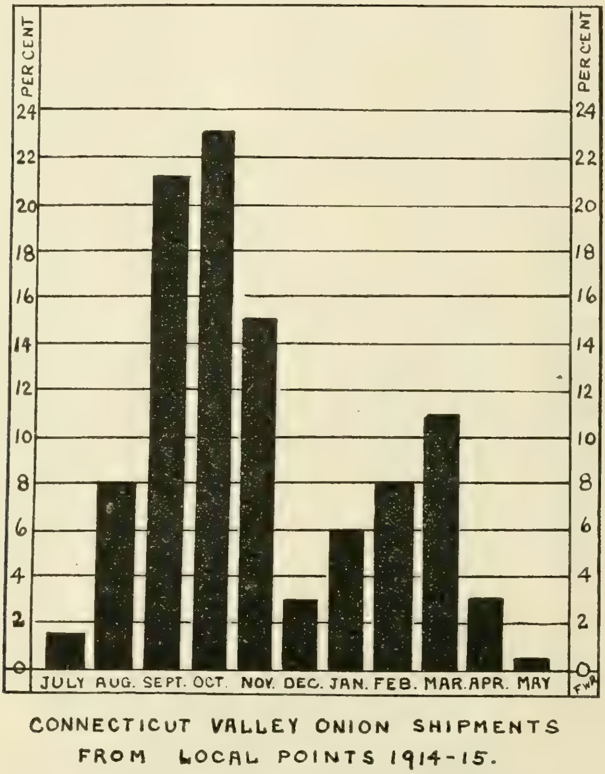


FIG. 22. — Compare this with Figs. 21 and 23, and note how an unsteady market affects shipments.

The 1914–15 season, on the other hand, shows the effect of a wavering and uncertain market. The unusually heavy shipping to the end of November, due to good prices for "sets" and early fall onions sold from the field, broke down the market so completely that it continued unsteady until the end of the shipping season. In fact, its unsteadiness, aggravated by an abundant Texas crop, so affected the market for "sets" during the 1915–16 season that many were sold below the actual cost of production.

The shipments for the 1915–16 season show the peculiarities due to a good season from the standpoint of price. Early harvesting was delayed by numerous rains and lack of sunshine. Besides, the activity of the buyers and the reports of the Ohio and Indiana floods gave some farmers courage to hold the crop. This explains in part the unusually light shipment for September, and the correspondingly heavy shipment for October. The diseased condition of many crops, which made the onions undesirable for storage, was another reason for the heavy shipments during October.

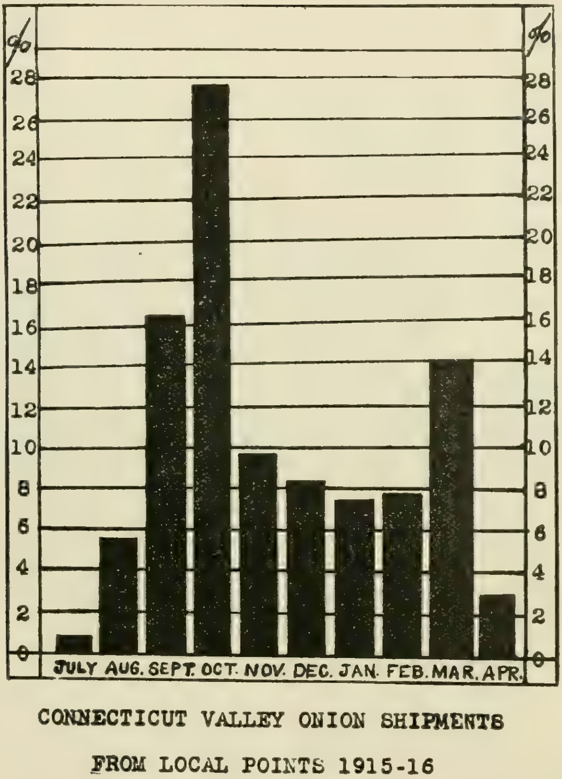


FIG. 23. — Note the exceptionally large quantity shipped in March. Onions were held as long as possible for higher prices, but had to be shipped in March (1) to prevent excessive loss through shrinkage, and (2) to escape competition with the Texas crop reported to be unusually large and early.

The shipments during November, December, January and February show a marked uniformity similar to that of the 1913–14 shipments. The heavy shipping in March was occasioned by the fact that onions were not keeping and the market was good. Besides, there were reports of an unusually heavy and early Texas crop. As a result, barely 3 per cent. of the crop remained in the local storages after April 1.

Cost of Local Storage.

The usual items in the cost of storage have been considered, but since rates and methods of insurance and taxation differ in various sections, a brief explanation of the figures used in our computation seems advisable. The valuations of storages and equipments were furnished by their owners. Five per cent. of the valuation was allowed for interest. The tax rate varied in 1915 from $16.50 to $20 per $1,000; hence, the flat rate of $17 per $1,000 was used. There seems to be no uniform principle upon which storages and equipment are assessed for taxation, but in every instance studied the assessment never exceeded 65 per cent. of the actual value as given by the owners; hence, this maximum ratio was used as the basis of taxation.

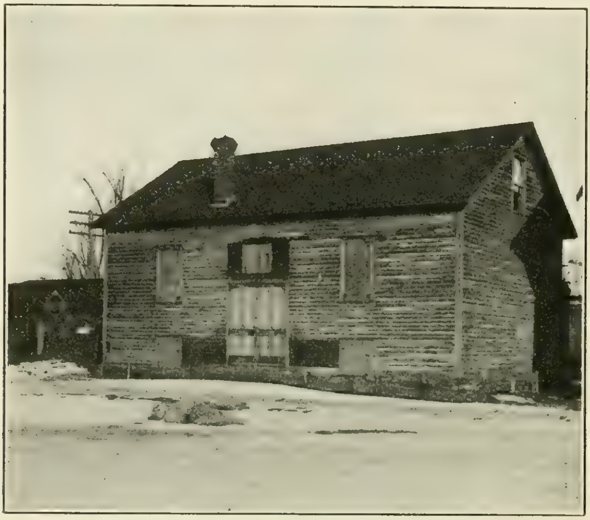


FIG. 24. — The first onion storage built west of the Connecticut River, at South Deerfield. This storage is still used. The pile of rotten onions on the left is an illustration of loss through shrinkage.

Insurance.

The rate of insurance on buildings varies according to the location of the building and the material of which it is built. The usual rate, however, is $1.25 per $100 per year. The total valuation of storages and equipment was given as $211,000; therefore, $200,000 seemed a generous estimate of the insurance carried.

Few reliable figures could be secured upon onion insurance. A good many of the onions are not insured, while others are insured only at a certain percentage of their actual value. In view of this difference in practice among storage men and in rebates allowed because of short-term insurance, the onions (486,900 bushels) were figured at 30 cents a bushel, and the rate of insurance taken at $6 per $1,000 per year.

Depreciation.

Four and one-half per cent. is a fair allowance for depreciation and repairs. It was arrived at in this way. The ratio of the value of the storage to its equipment is approximately 3:1, but the life of the building is about forty years, while that of equipment, especially crates, is possibly only fifteen years; hence, depreciation for crates is 6.6 per cent., and for storage 2.5 per cent. Taking three times the building depreciation, plus once the equipment depreciation, and dividing by four we have 3.5 per cent. — the depreciation of buildings and equipment. For repairs 1 per cent. was allowed.

In accordance with the above principles the distribution of the overhead charges for storage of onions is as follows: —

Number of storages considered,	22
Capacity (bushels),	486,900
Total valuation, including equipment (crates, bins, derricks, etc.),	$211,000 00
Interest on investment at 5 per cent.,	$10,550 00
Taxes, $17 per $1,000 on 65 per cent. of valuation,	2,331 55
Insurance on buildings and equipment ($1.25 per $100 on $200,000),	2,500 00
Insurance on onions (486,900 bushels at 30 cents) $6 per $1,000,	876 42
Depreciation at 3½ per cent.,	7,385 00
Repairs, 1 per cent.,	2,110 00
Total overhead charges,	$25,752 97
Overhead charges per bushel,	$0 053

In all these computations rather high valuations were made, so that $0.053 per bushel seems a generous allowance for overhead charges.

Specific Problems of Storage.

The first problem of the storage man is to secure a sufficient quantity of good storable onions. He solves this by purchasing early, especially when the crop is reported short. In many cases contracts between grower and dealer are made even before the onions are harvested.

His second problem is to reduce shrinkage to a minimum. Shrinkage is dependent upon the quality of the onions, the temperature changes of the season and artificial atmospheric regulation of the storage. Over the first two factors the storage man has practically no control except in so far as he may select storable onions and ship immediately all other purchases; but some years even the most carefully selected stock keeps poorly. This was notably true of the product stored in 1915–16. The temperature of the storage should be kept as near 30° F. as possible by using the ventilators.

The problem of timing shipments to conform to the rise and fall of the market necessitates an acquaintance with the condition of the onions in storage, transportation facilities and methods, and onion market conditions in all the principal cities.

The selection of safe and reliable men at the receiving end is another problem. This is necessary, for even honest business men are strongly tempted to refuse consignments if the market is on the decline when they arrive. This is one of the chief reasons why the small farmer cannot risk direct shipment.

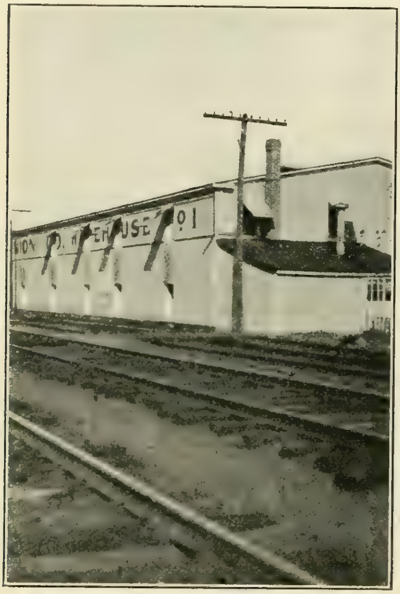


Fig. 25. — A newer type of onion warehouse. Note the number and arrangement of the ventilators. A portion of a roof ventilator is shown to the right of the brick chimney.

Still another problem is to keep down the cost of doing business; that is, office expense, up-keep of storage, purchase of bags and labor expense. In a large way these costs per bushel seem to vary immediately with the quantity stored provided the storages are filled to capacity.

Shrinkage.

The data collected from twenty-two storages show that the shrinkage for the season of 1914–15 was about 10 per cent. of the quantity stored. It is seldom less than 7 per cent. for any one year, and hardly ever exceeds 15 per cent., except for onions held until the very last of the season. The crop of 1915 was unusual in this respect. The wet season of 1915 caused the onions to become affected with "slippery skin" and "center rot," so that losses as high as 35 per cent. were reported. The average shrinkage, however, probably did not exceed 20 per cent.

Shrinkage losses as well as the cost of extra handling must be considered in computing the total cost of storage. In figuring the shrinkage loss, the value of the onions stored is taken at $1.14 per 100 pounds, which represents the average price paid to farmers for the three years, 1913–15.

The cost of extra handling from storage and loss by shrinkage on the basis of 250 bags would be as follows: —

To regrade and sack, 5 men 1 day at $1.75,	$8 75
To load and unload, 1 man 2 hours at 17½ cents,	35
To haul to station, man and team 1 day,	5 00
Shrinkage, 25 bags at $1.14,	28 50
Total cost, shrinkage and handling,	$42 60
Total cost per bushel (450 bushels),	$0 095
Cost per bushel *not including shrinkage*,	031

It is to be noted, however, that the item for regrading and sacking is considerably higher during a season when onions keep poorly.

The 9.5 cents is the cost of removing from storages located at some distance from the railroad. For storages from which onions may be loaded into the car directly this cost is about 8⅛ cents per bushel. Summarizing these costs, we have —

	Including Shrinkage.	Not Including Shrinkage.
Overhead charges per bushel (page 93),	$0 053	$0 053
Removal from storage and shrinkage,	095	031
Total, per bushel,	$0 148	$0 084

We have previously shown that the usual charge for storage in commercial warehouses is 23 to 25 cents per bag of 2 bushels, not including shrinkage. This contrasts with an actual average cost of 17 cents per bag. This cost may be still further reduced if the farmer does the work himself at a time when he has little or no other work.

Immediate Sale or Storage.

In the light of the above costs and the experiences of storage men in the valley should a farmer sell directly from the field or store? The question is one of relative profitableness, the chief reason for holding being the hope of selling at a higher price. It is readily seen that prices received must be high enough to pay interest on the amount for which the onions might have been sold in the fall, to cover loss by shrinkage and to pay for storing and the extra cost of handling. The cost of these, with the exception of the item for interest, is 14.8 cents per bushel, or approximately 29.5 cents per bag.

The four-year (1911–15) average monthly wholesale price per 100 pounds on the Boston market as given in the Quincy Market Bulletin was as follows: —

September,	$1 62	January,	$1 94
October,	1 52	February,	2 34
November,	1 72	March,	2 45
December,	1 70	April,	2 46

While these prices are somewhat higher than the grower received, the farmers' prices for the same months would show about the same variation. The table shows that the average March price is about 52 per cent. higher than the September price.

We are now able to estimate the farmer's possible gain by holding his crop. The table above shows a steady rise in price from December to April. The question is whether this rise is sufficient to cover the items of extra expense before enumerated.

As an illustration, let us take the case of a farmer who has 1,000 bags of onions. By selling in September at the price listed he would receive $1,620. The interest on this at 5 per cent. for five months would be $33.75, or 3.4 cents a bag. Adding to this the loss from shrinkage, overhead charges for storage and extra handling, we have a total cost of 33 cents a bag. The average price during the storage months is $2.18 per bag. This is 56 cents above the September price, 66 cents above the October price, and 46 cents above the November price. According to these figures it would pay this farmer to store.

The general plan, however, is for the small grower to rent storage space at 25 cents a bag. Add this to the increase for shrinkage, 11.4 cents, and interest, 3.4 cents, and we have a total advance of 39.8 cents per bag. Even under this plan the farmer who stored would gain over his neighbor who sold in September and October; moreover, it appears that the charge of 25 cents per 100 pounds is higher than necessary for the commercial storage of onions. Of course, the man who holds his crops for any particular season must take chances on shrinkage and on receiving the average price indicated.

Local Cold Storage.

No onions are placed in cold storage in the valley, though one of the storages is so constructed that a cold-storage plant may be installed at any time. Local warehouses are used almost exclusively until March, and after that date some onions are put into cold storage in Boston and New York where they are kept as late as the first of May.

In the opinion of a number of leading growers and storage men, a cold-storage plant in the valley would be a profitable investment. Others argue that since the Connecticut Valley onions must be closed out as soon as possible after the middle of April because of the arrival of the Texas Bermudas, the period would be too short for the profitable operation of the expensive equipment necessary; moreover, the shrinkage of onions in cold storage is usually high. In spite of every precaution the onions seem to absorb moisture which greatly impairs their keeping quality.

Terminal Storages.

Terminal storages are of two kinds: —

1. *Common.* — Of the large quantities of onions shipped to the principal markets during the months from September to December, a great many are held in lofts, cheap warehouses and potato warehouses for later sale.

While the quantity so held varies with the season it is usually large in November and December, especially during years when the supply in the valley is large and the market rules firm. The charge per month for ordinary common storage is about 6 cents per bag.

2. *Cold Storage.* — The principal cold storage for Connecticut Valley onions is the Quincy Cold Storage and Warehouse Company in Boston. It is located on the Union Freight Railway, connecting with all railroads entering Boston. It has a capacity sufficiently large to take care of any quantity which dealers may send. Very few onions are put into this storage before March. In 1915 the quantity by months held by this storage was as follows: —

	Bags.
March,	27,744
April,	4,005
May,	3,000

The charge for terminal cold storage in less than carload lots is 15 cents per bag the first month and 12.5 cents per month thereafter; in carload lots 12 cents per bag per month; if stored in barrels the charge is 20 cents per barrel for the first month, 15 cents for the second, 10 cents for the third and 5 cents for the fourth, making a total of 50 cents per barrel for the maximum period stored.

Terminal storage is of great importance in onion distribution. Shipments cannot always be properly gauged as to time and quantity. By holding excessive shipments in terminal storages and releasing them when shipments do not meet the demands of the trade the market may be steadied to a considerable degree.

TRANSPORTATION OF ONIONS.

Local Transportation.

Onions sold for immediate shipment are bagged in the field and hauled to the local shipping point on an ordinary farm wagon with a low bed. While the length of wagon haul varies, the average, as previously stated, does not exceed 2½ miles. The main roads in the district are excellent, especially those leading from Sunderland to South Deerfield and from North Amherst to Amherst over which thousands of bushels are moved. These roads have only a few steep grades, and two horses can easily haul a load of 60 to 65 bags.

The branch roads are generally sandy and unimproved, which makes hauling difficult and increases the cost accordingly. The average cost of local transportation from field to local storage or shipping point is approximately 1 cent per bushel. Storage warehouses are either on the railroad or within an average distance of 2½ miles. If on the railroad, the onions are put into cars directly from the warehouse. Those at some distance are sufficiently near to enable a team to make at least four trips a day. The cost of such transportation is discussed under "Storage" (page 95).

Transportation from Local Shipping Points.

Transportation routes and the distances between the local shipping points in the Connecticut Valley onion district and Boston and New York are shown on the map below.

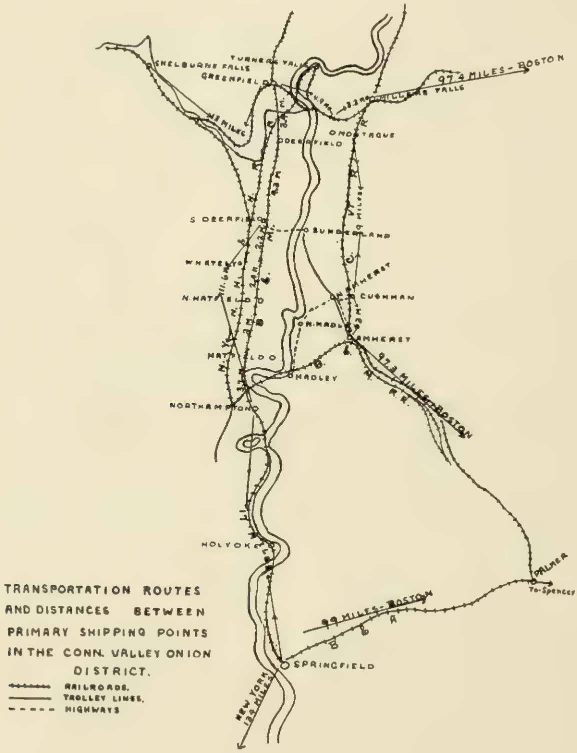


FIG. 26.

Trolley Transportation.

The Amherst and Sunderland Street Railway running on the east side of the Connecticut River between Amherst and Sunderland is the only trolley line in the valley which has a franchise and equipment for handling freight cars. At Amherst this electric line connects with the Boston & Maine Railroad, running between Northampton and Boston. This trolley freight service is used by the storage men and a number of the large growers in the vicinity of North Amherst. It is a great convenience in the autumn when the farmer is pressed for time, and for late winter shipments it is almost a necessity on account of the danger of freezing while in transit by wagon. Until December ordinary box cars are used, but thereafter refrigerator cars are used almost exclusively.

Until Sept. 1, 1914, the rate per carload to Amherst was $6 from Sunderland and $5 from North Amherst. Since then the charges have been increased to $10 from Sunderland and $8 from North Amherst. These charges are considered too high, and a good many of the shippers are now hauling onions directly to the railroad stations at Amherst, Cushman, Hadley and South Deerfield. In spite of the heavy crop harvested during the season 1914–15 the shipments by trolley showed a decided falling off.

The trolley shipments by months from 1913 to 1916 were as follows: —

MONTH.	1913-14.	1914-15.	1915-16.
	Cars.	Cars.	Cars.
August,	2	–	1
September,	10	2	9
October,	19	24	13
November,	5	9	–
December,	6	2	2
January,	9	7	9
February,	11	11	12
March,	16	18	18
April,	7	1	8
Total,	85	74	72

Railway Transportation.

Three lines of railroads serve the Connecticut Valley growers — the Boston & Maine, the New York, New Haven & Hartford, and the Central Vermont. The principal shipping points in the valley, together with the number of cars shipped from each point during the three seasons of 1913, 1914 and 1915, are given below: —

STATION.	BOSTON & MAINE RAILROAD.			NEW YORK, NEW HAVEN & HARTFORD AND CENTRAL VERMONT RAILROADS.		
	1913-14.	1914-15.	1915-16.	1913-14.	1914-15.	1915-16.
Amherst,	163	230	153[1]	4[2]	8[2]	7[2]
Deerfield,	36	61	38	–	–	–
Greenfield,	–	15	14	–	–	–
Hadley,	305	476	433	–	–	–
Hatfield,	460	575	429	–	–	–
Montague,	24	43	39	–	–	–
Montague City,	–	1	–	–	–	–
Northampton,	49	57	55	–	–	–
North Hatfield,	462	577	445	–	–	–
South Deerfield,	1,189	1,424	1,462	47[3]	84[3]	51[3]
Whately,	217	262	210	–	–	–
Cushman,	–	–	–	–	13[2]	4[2]
	2,905	3,721	3,278	51	105	62
	51	105	62	–	–	–
Totals,	2,956	3,826	3,340	–	–	–

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[1] In 1915–16 a considerable number of cars of onions produced in Amherst were shipped by way of Sunderland and Hadley, which explains the apparent drop from 163 cars in 1913–14, to 153 cars in 1915–16.

[2] Central Vermont.

[3] New York, New Haven & Hartford.

The shipping season begins about the middle of July and ends the latter part of April or the beginning of May. The accompanying chart gives the shipments by weeks for the seasons of 1913–14, 1914–15 and 1915–16. Very few shipments suffer any marked loss in transit. As a rule, onions that arrive in poor shape at their destination were questionable when consigned. Occasionally, however, they suffer through extremes of heat or cold. Most of these complaints come during the early fall and the late spring.

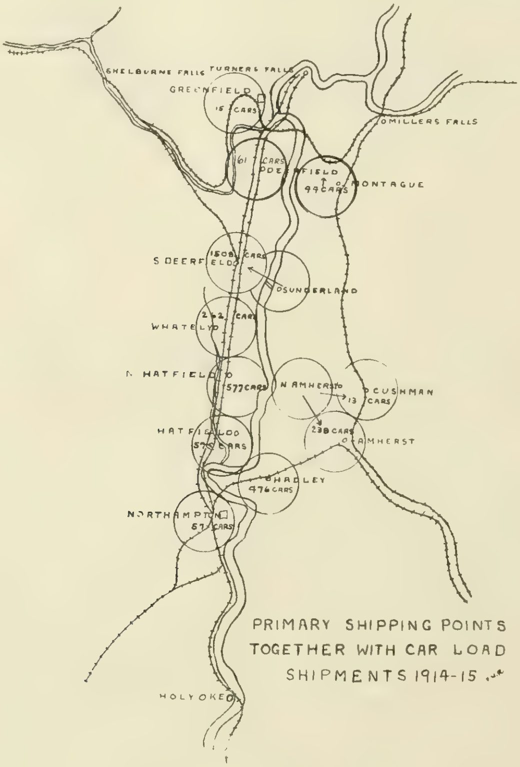

Fig. 27. — The shipping points of the Connecticut Valley. This map shows the relative importance of the various districts as onion-producing centers by the number of cars shipped from each station during the 1914–15 season. South Deerfield, from which point all the Sunderland onions are shipped, is by far the most important shipping point in the valley.

Methods of Shipping.

Practically all shipments are made in 100-pound bags. Occasionally a car is loaded in bulk, but this method of shipping is not considered advisable, because the onions are likely to heat especially during September and October when the weather is warm and the onions are not yet well cured. Until December ordinary freight cars are used, but after that date refrigerator cars are used almost exclusively. These are frequently

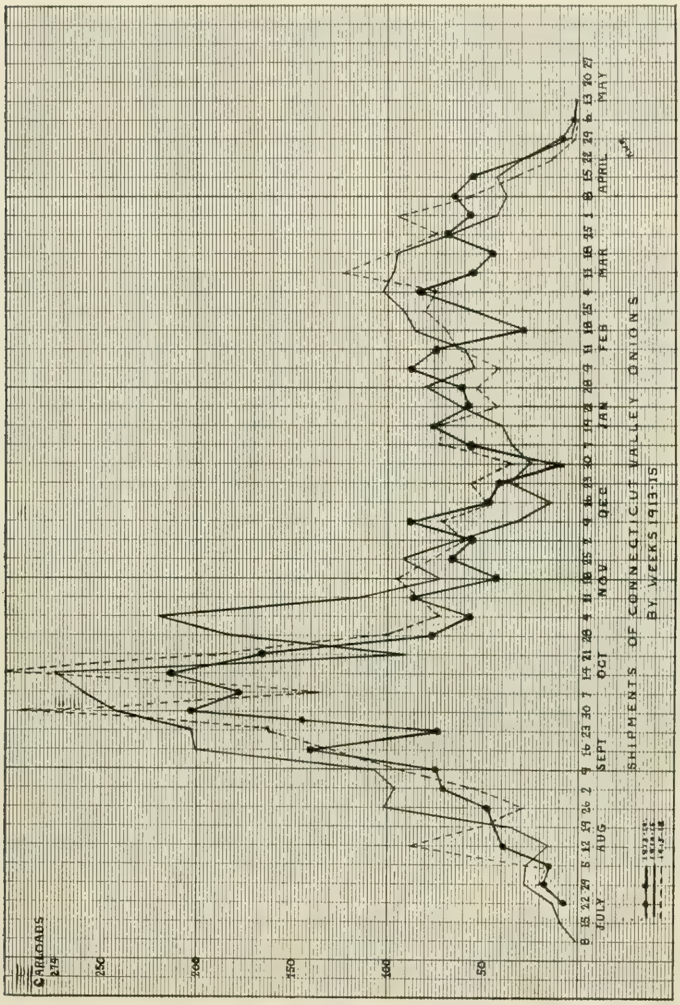

Fig. 28. — Note the exceptionally heavy shipments during the last two weeks in September and the first three weeks in October, the light shipment during Christmas week and the heavy shipments in March.

lined with heavy paper to keep out the cold. In extreme weather the cars may be heated with oil stoves.

The average carload contains 250 bags, approximately 500 bushels. The freight rates per 100 pounds in carload lots from different shipping points in the valley to some of the principal markets are as follows: —

	Cents.
Amherst to Boston, Central Vermont Railroad,	11
Cushman to Boston, Central Vermont Railroad,	14
Cushman to Norwich, Ct., Central Vermont Railroad,	13
Cushman to Stafford, Ct., Central Vermont Railroad,	12
Greenfield to Boston, Boston & Maine Railroad,	12
South Deerfield to Tampa, Fla., Boston & Maine Railroad,	42
Amherst to Boston, Boston & Maine Railroad,	12
Amherst to New York, Boston & Maine Railroad,	17
Hadley to Boston, Boston & Maine Railroad,	12
South Deerfield to Boston, Boston & Maine Railroad,	13
South Deerfield to New York, Boston & Maine Railroad,	13

PROBLEMS OF TRANSPORTATION.

Shortage of Cars.

When shipping is at its height some trouble is experienced in getting a sufficient number of cars. This is not always due to a real shortage of cars, but rather to a lack of extra track for the placing of empty cars at some of the local shipping points in the valley. In general, however, there is little complaint against the railroad companies in this respect.

More frequent complaint comes because of delays while in transit. Onions which leave the valley on Thursday should arrive at Boston the next morning in time for the Friday morning market. Shipments which do not arrive at that time must be held over until the following week, because Saturday's market is usually small. During the fall such delays are especially frequent making it difficult to time shipments properly.

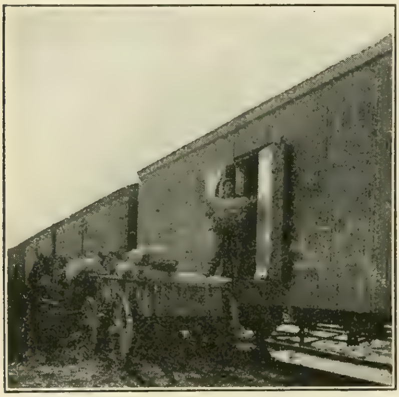

FIG. 29.— Loading onions into the car. Note the coarse mesh bag and the typical method of handling it. After December 1 refrigerator cars are used almost exclusively.

Demurrage.

Demurrage in Massachusetts is regulated by a commission which has accepted without any prescribed regulations the application of the "unified code" or "national car demurrage rules" by the railroad companies. Among other things this code allows forty-eight hours for loading and unloading cars, such time to be computed from the first 7 A.M. after placement and notice. Sundays and holidays are excluded in the computation of time. The charge is $1 per day or fraction thereof after the expiration of "free time" until cars are released. It also makes provision for an extension of time when it is impossible to load or unload on account of weather conditions, or when serious injury would result to the freight from loading or unloading under adverse conditions.

The New England Demurrage Commission, with headquarters at Boston, was established in 1910. All the lines in New England are members of it, and, while each line publishes and files its own demurrage tariff, a demurrage commissioner has general oversight of all demurrage matters. He is "to arbitrate all doubtful or disputed cases growing out of the application of the demurrage rules which the shippers or the roads desire to refer to him." As an impartial investigator and referee he attempts to secure from the railroads their best possible service, and from shippers co-operation by the prompt release of cars in order that commerce may be facilitated and that efficiency of transportation may be increased. Cases of demurrage charges against Connecticut Valley shippers are comparatively few.

There are certain dealers, however, who use cars for storage purposes at local shipping points. One dollar a day is not a heavy charge for keeping onions protected from the weather and ready to rush to market at the most opportune time. This is not a common practice, however, being limited largely to buyers who have no storage of their own, and to the late autumn in seasons when the market rules firm.

PRICES OF ONIONS.

Supply and Demand.

Statistics secured from the various transportation agencies for the shipping seasons 1913–15 show that the primary markets for Connecticut Valley onions are the principal cities of the New England and Middle Atlantic States. A considerable number are also finding their way into the markets of Canada and the South Atlantic States, and recently smaller shipments have even been made to the Philippines, Cuba and Europe.

The principal cities, with the number of cars of onions shipped to each during the seasons of 1913–14 and 1914–15, were as follows: —

CITY.	Number of Cars, 1913-14.	Number of Cars, 1914-15.
Maine.		
Auburn,	5	11
Bangor,	24	39
Portland,	81	96
Rockland,	2	11
Total Maine markets,	147	212
New Hampshire.		
Keene,	22	12
Manchester,	14	34
Nashua,	6	11
Total New Hampshire markets,	66	99

City.	Number of Cars, 1913-14.	Number of Cars, 1914-15.
Vermont.		
Norwich,	11	16
Rutland,	4	8
Total Vermont markets,	31	47
Massachusetts.		
Boston,	707	983
Brockton,	10	27
Greenfield,	14	35
Haverhill,	7	21
Holyoke,	26	13
Lawrence,	22	47
Lowell,	27	38
Lynn,	20	18
New Bedford,	30	34
North Adams,	14	21
Northampton,	43	35
Pittsfield,	14	18
Salem,	10	13
Springfield,	71	70
Worcester,	59	104
Total Massachusetts markets,	1,173	1,589
Connecticut.		
Bridgeport,	27	38
Hartford,	57	60
New Britain,	10	21
New Haven,	70	84
New London,	5	12
Waterbury,	30	41
Total Connecticut markets,	233	287
Rhode Island.		
Providence,	189	248
Total Rhode Island markets,	196	258
New York.		
Albany,	36	22
Barclay Street,	206	195
Brooklyn,	22	12
Buffalo,	14	2
Harlem River,	107	196
New York City,	38	85
Schenectady,	16	17
Troy,	26	26
Total New York markets,	479	571

City.	Number of Cars, 1913-14.	Number of Cars, 1914-15.
New Jersey.		
Newark,	3	13
Total New Jersey markets,	10	37
Pennsylvania.		
Philadelphia,	180	194
Pittsburgh,	66	16
Total Pennsylvania markets,	262	233
Maryland.		
Baltimore,	30	14
Georgia.		
Atlanta,	6	2
Total Georgia markets,	12	8
Florida.		
Tampa,	11	16
Total Florida markets,	24	20
Tennessee.		
Total Tennessee markets,	13	1
South Carolina.		
Charleston,	2	31
Canada.		
Halifax,	1	10
Montreal,	15	18
St. Johns,	10	19
Total Canada markets,	27	64

The map below illustrates the breadth of the market and the relative importance of each State as a consumer of Connecticut Valley onions.

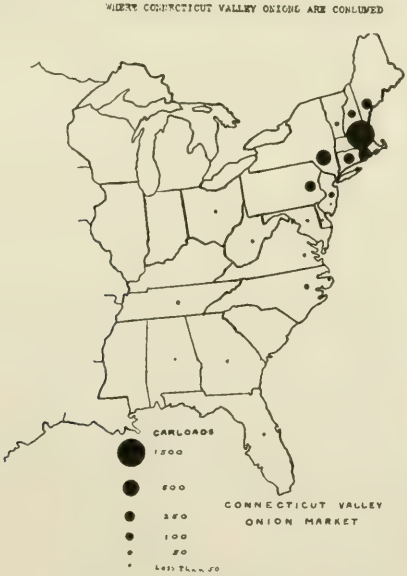

FIG. 30. — Where Connecticut Valley onions are consumed or reshipped, by States.

Varieties of Onions handled.

The principal competing varieties and the duration of each on the New England markets may be seen by a study of the accompanying diagram (Fig. 31). Strictly speaking, however, three varieties take care of the general onion trade in the New England States. They are the Connecticut Valley, supplemented to a greater or less extent by the New York and Ohio varieties, the Egyptian and the Texas Bermudas. Those from the Connecticut Valley rule from September until April. Texas Bermudas begin about April 10, and are at their height during May, June and July. The Egyptians fill in the gap between the going out of the Connecticut Valley onions and the coming in of the Texas Bermudas.

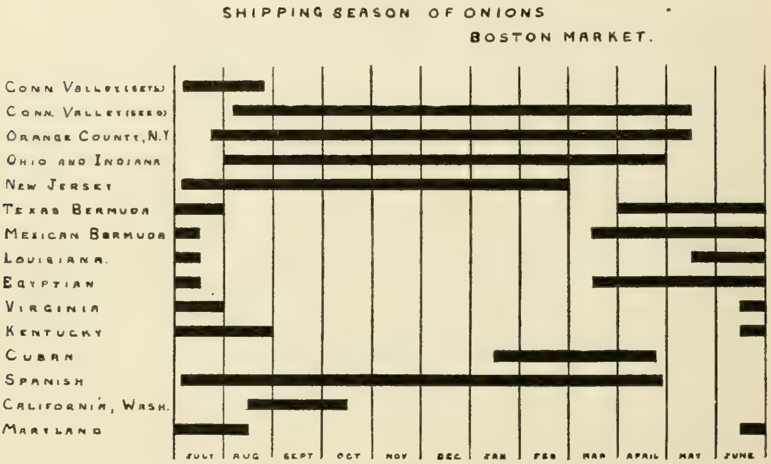

Fig. 31. — Duration of the different varieties on the Boston market. Note the chief competitors. A heavy Texas crop is disastrous to Connecticut Valley sets. The Spanish onions have a special trade, and do not really compete with the Connecticut Valley onions.

The Spanish onion, which is excellent in keeping quality and of very fine flavor, may now be had almost the year round. It has a trade of its own, and can hardly be called a competitor of the three varieties mentioned above. It should be noted, however, that the Ohio and New York varieties arrive on the New England markets about a week later than the onions from the Connecticut Valley and are their chief competitors through the season.

Variations in the Supply of Onions.

The supply of onions for four seasons on the Boston market is graphically represented by Fig. 32.[1]

In studying this chart one is impressed by the marked yearly and seasonal fluctuations. The causes for these may in many instances be

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[1] For the supply of onions in the commercial onion-growing belt, see Part I. of this Bulletin.

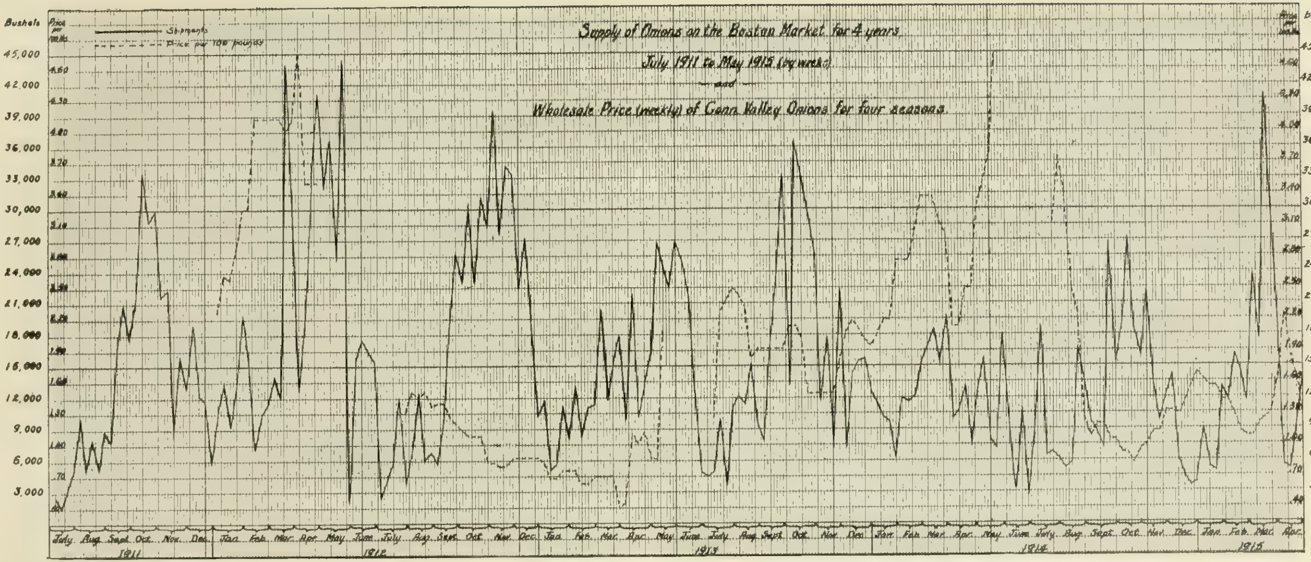

FIG. 32. — Supply of onions on the Boston market for four years, July, 1911, to May, 1915, and wholesale price (weekly) of Connecticut Valley onions for four seasons.

explained. The growing season of 1911-12, for example, was marked by severe droughts which resulted in a short crop of onions, small in size, but of excellent keeping quality. During this season most growers sold early at around $1.50 per bag, which they considered a fair price. But the buyer who sensed the situation stored and sold later at prices ranging from $3.50 to $4.50 per bag. It so happened that the southern crop in 1912 was late and very short because of frosts, which was another lucky break for the storage man.

Following the short crop of 1911 and the correspondingly high prices that winter, a greatly increased acreage resulted and 1912 onion production was overdone. The result was a record crop and very low prices. Then came the reaction, a smaller acreage for 1913, and a yield much reduced by drought and the thrips, but very good prices. The 1914 acreage was again very large, the yield exceptional and the prices very low. In 1915 the acreage planted was about normal, but the quantity harvested was very small on account of the exceptionally heavy rainfall and consequent floods which destroyed thousands of acres in the commercial late onion-growing belt. As might be expected the price was satisfactory to both the grower and the dealer.

Marked variations in the supply may, therefore, be attributed to two reasons — the price the previous season and the general weather conditions during growth and harvest.

Variations in Demand.

For seasoning purposes the onion is used in practically every home, and the demand for good onions continues throughout the year. In this respect it has practically no competing vegetable and is purchased in the small quantities demanded by the average home, no matter whether the price is high or low. In this field the demand is stable or inelastic. In our own markets, however, the demand seems to be increasing, due, first, to the growth of our foreign population, many of whom are from southern European countries and are large consumers of onions, and, second, because the onion is used as a vegetable in an increasing number of homes at all seasons of the year.

Wholesale Prices of Onions on Boston and New York Markets.

The weekly prices of Connecticut Valley onions per 100-pound bag for the four seasons, 1911-15, on the Boston market, according to the Boston Produce Market Report, are plotted on Fig. 32, page 107.

Two other charts are presented. The first (Fig. 33) shows the average *monthly* prices for four seasons on the Boston market. A study of this chart indicates among other things (1) that, in general, an exceptionally good season is followed by a poor one, and (2) that for any one season the September, October and November prices are fairly constant. The second chart (Fig. 34) shows the difference between the wholesale quotations at

New York and Boston. The figures for New York were taken from the New York "Packer," and for Boston from the Boston "Produce Market Report." It is evident from this chart that the differences in price in these markets during a normal season are not very marked.

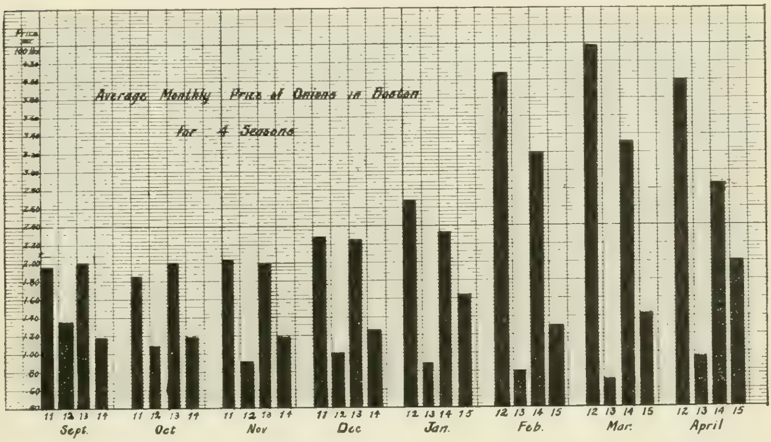

FIG. 33. — Average monthly (wholesale-to-jobber) price for four seasons. This chart shows that it is not always profitable to hold onions. While storage men who held the 1911 and 1913 crops profited greatly by so doing, those who held the 1912 crop lost heavily.

The wholesale prices given above are the prices which the retailer pays to the large wholesaler and jobber. They represent the cost in the valley plus transportation charges, cartage from car to wholesale distributor's place of business, and losses and distributor's profit.

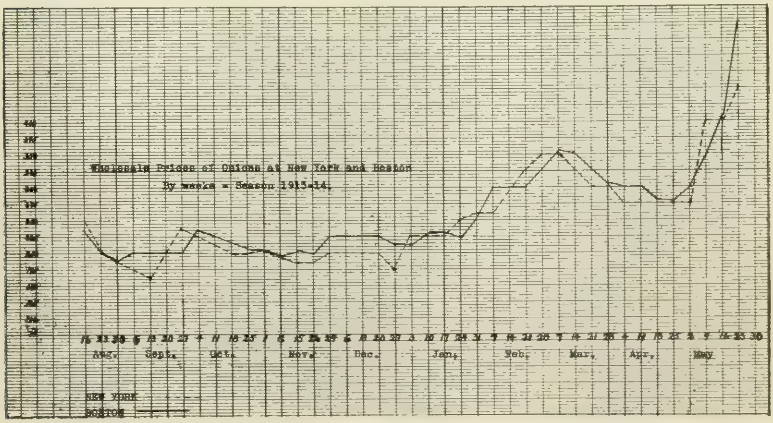

FIG. 34.

Prices to Farmers.

The prices paid to farmers for 100 pounds of onions in 1913, 1914 and 1915 were approximately as follows: —

1913.	
August 10 to 17,	$1 30–$1 45
August 17 to 25,	1 35– 1 40
August 25 to September 10,	1 30– 1 55
September 10 to 30,	1 25– 1 50
October 1 to 30,	1 40– 1 50
1914.	
August 5 to 20,	$1 50–$2 25
August 20 to 30,	1 25– 1 50
September 1 to 15,	75– 1 10
September 15 to 20,	60– 70
October 1 to 15,	40– 60
October 15 to 30,	50– 60
November 1 to 15,	75– 1 00
1915.	
August 20 to 30.	$0 90–$1 00
September 1 to 15,	1 00– 1 45
September 15 to 30,	1 15– 1 50
October 1 to 15,	1 35– 1 65
October 15 to 30,	1 25– 1 40

These prices are for onions delivered at the cars or warehouses. The sack in practically every case is furnished by the dealer without cost to the farmer. Prices paid to farmers show wide seasonal and individual variations; selling the crop a few days earlier or a few days later may make a decided difference in the amount which the farmer receives. Not infrequently the writer heard these statements: "We sold at just the right time, because two days later the bottom dropped out of the onion market completely," or "We made a mistake when we sold so early, because the cry 'overproduction and low prices later' was not true." Both these statements are undoubtedly correct, because the condition of the market does control the price, and the condition of the market in turn is ultimately controlled by the available supply and the effective demand.

But there are other variations in prices — variations between farmers who sell on the same day, often to the same dealer. There are numerous reasons for such variations. They may be the result of an inferior quality, due to inferior culture or soil, or defective methods of harvesting and curing, or possibly failure to give proper attention to grading, bagging or handling. These factors all enter into the making of a standard marketable product put up in the best possible shape. Correctness and reliability of grading and packing are the farmer's "market character," and the buyers are quick to recognize a farmer's reputation for quality and honest practice. Such a reputation undoubtedly pays.

When onions are bought early, *i.e.*, before they are harvested, a contract is generally given by the dealer, and the price to the farmer is the named quotation, but deductions are made if the onions are not delivered in accordance with the terms of the agreement. To make the contract binding, part payment on the crop is frequently advanced by the dealer. Quite frequently the price quoted is for primes, which means that one-half the price will be paid for picklers. The more common practice, however, is to sell the entire product at so much per bag. In any case the farmer does the screening and grading, subject to the conditions stipulated in the contract. Too frequently the producer either willingly or carelessly fails to live up to his agreement. Dealers are emphatic in their contention that owners of land should supervise the screening done by their share tenants. Only in this way, they say, can the responsibility be placed where it belongs.

The diagram below shows the variations in prices paid producers through August, September, October and November for three seasons.

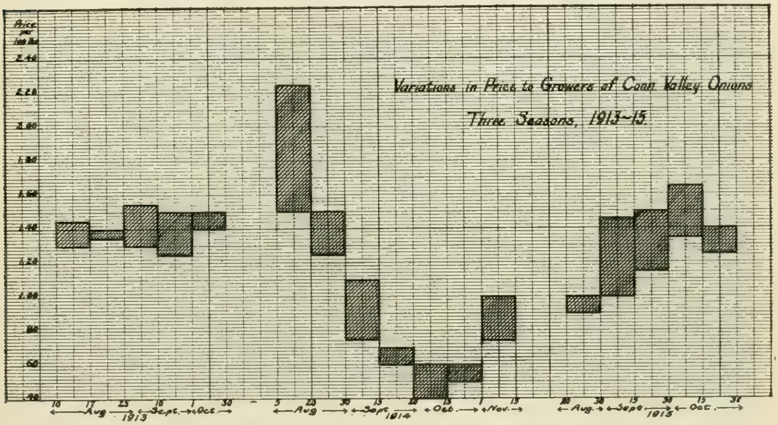

FIG. 35. — Variations in price to farmers. Some farmers must have had onions of inferior quality or lacked bargaining ability.

A study of this diagram is illuminating. Are the conditions of the market wholly responsible for this wide range of prices to farmers? It may explain variations for sales early or late in the season, but it would hardly account for the different prices paid on the same day even by the same dealer for crops of similar quality. It would seem that the producer is to a large extent responsible. At any rate, he is frequently not marketing his product at the best possible price.

If price differences are due to quality then the problems of seed, fertilizer, culture and harvesting should be investigated. If the quality is right then the failure to get the real market value must be explained by the producer's inability to sell advantageously. This is a problem of marketing. To assist in the solution of this problem is rendering first aid to the farmer.

Selling ability depends upon a great many things — a knowledge of general crop conditions, of marketing conditions, of current price quotations, of the onion supply in and out of storage, of the requirements of the market as to standard packing and grading, and upon ability to bargain.

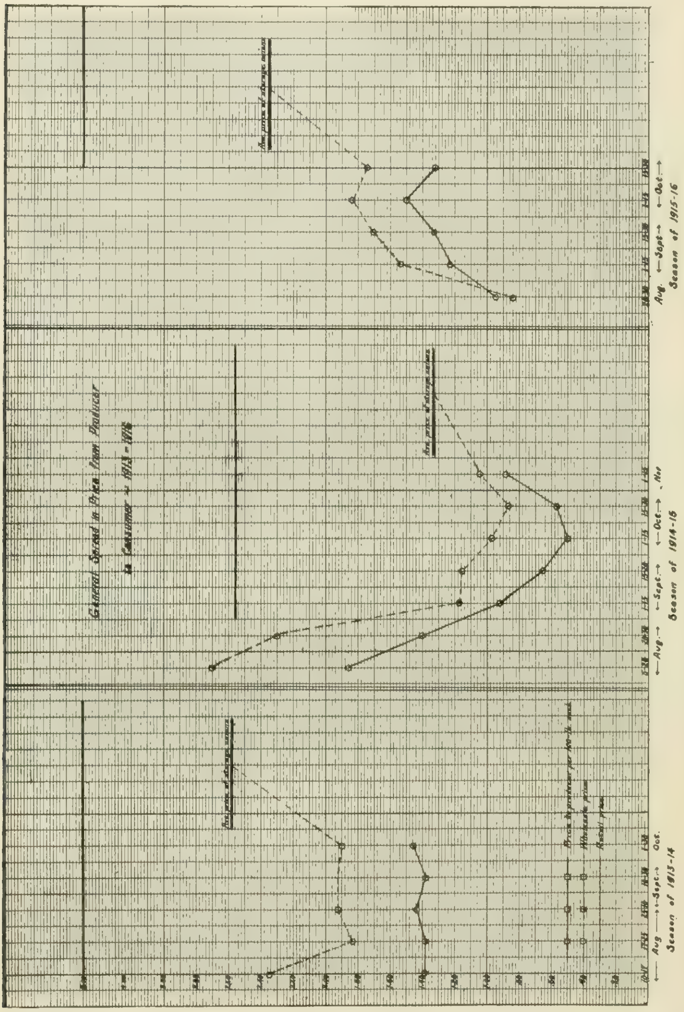

FIG. 36. — Spread in price. The above chart shows the price to the producer during the harvesting season, the wholesale price quotations and the retail price. Notice how the farmer's price compares with the wholesale quotations, and the fluctuations of the latter as compared with the unvarying retail price.

All these are effective selling arguments for the producer. Again, such knowledge must help the farmer in deciding when is the best time to sell. One must always keep in mind that a crop sold from 10 to 20 cents a bag less than the normal market price means a decided curtailment of the producer's income.

In Fig. 36 an attempt is made to show the spread between the price to the farmer, the wholesale price and the consumer's price.

Distribution Routes.

Onions shipped from the valley may reach the consumer through a number of different channels. It is our purpose to point out only the routes which the great bulk of onions takes, and to note the general spread of price from the producer to the ultimate consumer.

Heavy delivery charges and extra expense in the handling and packing of small quantities account for the fact that comparatively few sales are made directly from the producer to the consumer. There are, however, a considerable number of sales made directly to the large retailer, but such sales are usually in quantities less than carload lots.

The vast quantity of onions to be moved and the limited time in which to move them has brought into use our rather complex process of handling them through a chain of marketing specialists. The principal line is from producer to local dealer, to car-lot wholesaler, to jobber, to retailer, to consumer. Another is from producer to local dealer, to broker, to car-lot wholesaler, to jobber, to retailer, to consumer. In Fig. 37 an attempt has been made to show the principal onion-distributing channels. The interlocking circles are employed to show the rather intimate relations which exist between certain agencies connected with distribution; that is to say, certain firms perform the functions of two or three agencies. For example, firms may operate as commission men, car-lot wholesalers and brokers in such a way as to make it difficult to assign them to any definite class of middlemen.

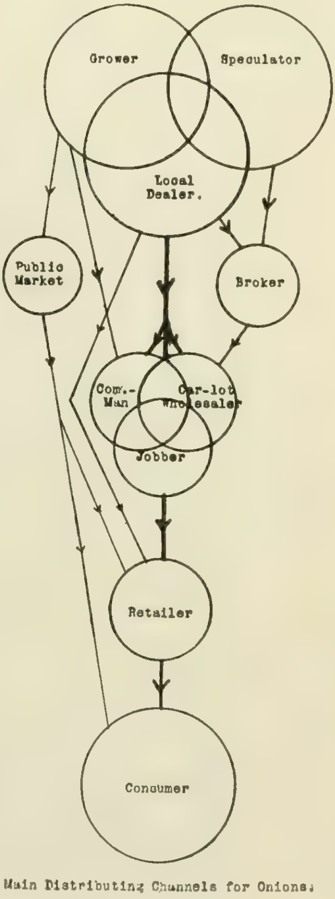

FIG. 37. — Main distributing channels for onions. The interlocking circles are used to represent the close relation existing between certain distributing agencies. The heavy line shows that the bulk of the crop goes from grower to local dealer, to car-lot wholesaler, to jobber, to retailer.

Secondary Distribution.

Primary distribution comprises the agencies engaged in the movement of onions from the farm to the wholesale receiver in the terminal market. Secondary distribution concerns itself with the distribution of onions from the time they reach the wholesaler's hands until they reach the ultimate consumer, through such agencies as car-lot wholesaler, jobber, wholesale grocer and retailer.

The places of the local dealer, commission man, broker and traveling buyer in onion distribution have already been noted. They come first in the present system of marketing and operate in the valley, purchasing for immediate sale, for speculation or for storage, and are agencies with whom the farmer may deal directly.

Fig. 38. — Delivering onions for the wholesaler. These onions are delivered to the warehouse or directly to retail stores. The drayage charge is 4 cents a bag.

Let us now briefly consider the functions of the middlemen who handle the product after it leaves the valley, *i.e.*, those engaged in secondary distribution.

The Car-lot Wholesaler.

The car-lot wholesaler acts as the primary distributor of onions arriving at the markets by breaking up the carload lots and starting distribution. He usually prefers to purchase outright through local dealers or brokers and sells to the jobbing or retail trade. When selling to jobbers the prices charged are generally less than those to the retail trade. This is done to protect the jobber and insure him at least a small margin of profit, when he in turn sells to the retailer.

Costs and Profits.

The profits of the car-lot wholesaler vary greatly. Buying outright and in large quantities he has a good chance for wide margins of profit and aims to make as much profit on each sale as possible. Of course, the risk he assumes is greater than that of any other wholesale middleman in the chain of onion distributors, with the possible exception of the local dealer.

Fig. 39. — Good Connecticut Valley onions at the wholesaler's place of business. No part of the bag needs hiding because this lot is well graded.

His business is subject to heavy overhead charges such as rentals, interest on investment and labor. The salaries of the regular salesmen vary from $25 to $85 per week. Considering his services and his cost of doing business his margin of profit is undoubtedly as small as that of any middleman concerned in onion distribution. He must count on 2 per cent. on gross sales for doing business.

Jobber.

The jobber is an intermediary between the commission man or car-lot wholesaler and the retailer. He usually buys from the former in less than carload lots — from 50 to 100 bags — and sells to retailers or other jobbers. His aim is to make quick sales, even on a relatively small margin, his profits coming through the rapid turnover of his capital. The jobber's cost of doing business is much the same as that of the car-lot wholesaler. It includes rent, help and interest on investment.

For the rapid and effective handling of extremely perishable produce his service could hardly be dispensed with, but in the distribution of onions that are properly graded and shipped the functions of the jobber are being assumed more and more by the car-lot wholesaler.

Retailer.

The retailer is last in the chain of distributors. Occasionally he purchases directly from the producer, but usually from the car-lot wholesaler or jobber. In the early fall large retailers frequently purchase a considerable quantity of onions so as to escape the advance in price which comes as soon as onions begin to be shipped out of storage. This accounts, in part, for the heavy shipments during October and November and the light shipments during December.

The various retailing agencies are the general store, the corner grocery, the public market and the street peddler. The retailers, as a rule, sell in small quantities by the pound, quart or peck. Of course in the early fall larger quantities are sold to institutions, asylums and other large consumers. The retailer must add at least 20 to 30 per cent. to the price he pays to cover his expenses and allow for a small margin of profit. As a rule, his prices vary very little during the season. In the early fall he may get his trade "educated," as he calls it, by filling a window with onions and using them as a leader for a week, selling them at a very reasonable price. In the fall of 1915, for example, a large Boston retailer sold onions at 4 cents a pound, 3 pounds for 10 cents, or 35 cents a peck. Later, the price was 5 cents a pound, 6 pounds for a quarter, or 50 cents a peck. Another retailer, running onions as a leader, sold them the first week at 5 pounds for 10 cents. Such sales advertise the onions and serve an excellent purpose in that they introduce another season's product to the public.

It should be noticed that wholesale prices do not group themselves at a certain definite level for the season, but differ even on the same day, within the same State. This is due to the sensitiveness of wholesale prices to such factors as quality, grade, length of storage, shrinkage, middleman expenses and cost of transportation.

In marked contrast to this is the retail price of onions which varies very little during the season, although it is well known that the wholesale cost is not the same; hence, the retailer often appears to be getting too large a share of the consumer's dollar. The fact that in the same city on the same day onions are retailed at prices ranging from 2 to 8 cents a pound shows that the retailers adjust themselves to their specific trade. Generally, however, the retailer charges a customary price of 5 cents a pound. He needs a wide margin because of waste, the small quantity of onions sold, and the high cost of doing business. This total cost for retail grocery stores, according to figures obtained by the Bureau of Business Research of Harvard University, ranges from 10.4 to 25.2 per cent. of net sales. The most common figure is 16.5 per cent. If the producer is to get more nearly his share he must do it by shortening the route between farm and retailer or consumer, because it does not seem possible that he can do the work of any of the middlemen for less than it is being done now; or he may co-operate with his neighbors and handle distribution along the lines of big business.

General Spread of Prices.

It is exceedingly difficult to analyze price figures with sufficient definiteness to determine price increment added by each of the various agencies through which onions are distributed. In the first place, reliable data on actual charges and prices received and paid by distributors are not readily obtainable; and, in the second place, margins of cost and profit vary greatly through the season and between different distributors.

From data collected at first hand it was found that when onions were selling at wholesale on the Boston market for $2.25 a bag, the retailer was charging $3.50 per bag, or in smaller quantities 5 cents a pound. By tracing this retail price back to the producer, it was possible to calculate with some accuracy the increase made by each agency and the reason for it.

Taking the average figures for the 1915–16 season: —

Ruling price paid by consumer per bag,	$3.50 to $5 = 100 per cent.
Ruling price paid by retailer per bag,	2.35 = 67.1 to 47 per cent.
Ruling price received by farmer per bag,	1.30 = 37.1 to 26 per cent.

The farmer's price is for onions sold directly from the field. Hence, the "spread" between $1.30 and $2.35, or $1.05 a bag, represents the cost of the container, costs or charges for storage, shrinkage, local dealer's profit, transportation and drayage charges, wholesale distributor's profit, and, in some cases, a brokerage fee.

The "spread" between the wholesale price, *i.e.*, the price paid by the retailer and the price to the consumer, represents the cost of retailing, losses through wastes and bad debts, and retailer's profit.

In Fig. 40 an attempt is made to present these facts graphically from a different angle. We are to imagine a bag of onions passing from farmer to housewife; as it passes from man to man each handler or distributor takes the toll for his services out of the bag; in other words, each takes his pay out of the onions he handles before he passes on the bag. Of course, the bag grows leaner and lighter as it proceeds. A farmer delivers to the local buyer 100 pounds of onions. The buyer takes the equivalent of 24.5 pounds for his services; hence, he actually loads on the cars the equivalent of 75.5 pounds. The railroad and drayman take 6.8 pounds, so that the amount delivered to the wholesale distributor is 68.7 pounds. The various wholesale distributors take 13.5 pounds of the 68.7, or about 19½ per cent., so that the retailer receives 55.2 pounds. He, in turn, takes out 18.2 pounds and delivers to the consumer 37 pounds; hence, 63 pounds represents the approximate cost of distributing 100 pounds of storage onions; or, stated in other terms, the consumer pays as much for 37 pounds as the grower receives for 100.

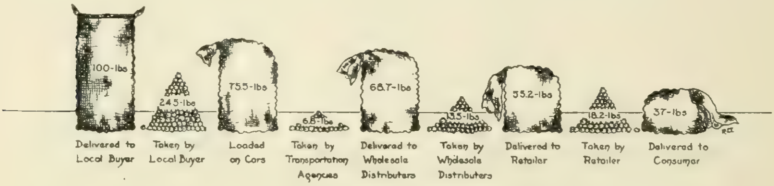

FIG. 40. — The cost of marketing Connecticut Valley onions.

RECOMMENDATIONS.

As a result of this investigation, the following recommendations are made: —

1. There should be in the hands of the farmers more general and definite information concerning the production (acreage, condition and estimated yield) and commercial movement of onions in and from the commercial onion-growing areas of the United States. Data from these sections are of great value in deciding upon the proper time for selling the crop.

2. The average onion grower is not giving sufficient attention to the problems connected with the curing, screening and grading of onions. The quality of the crop and the condition in which it is delivered to the buyer have a marked effect on the price. The requirements of the markets which are supplied with Connecticut Valley onions should be carefully studied and promptly met. This naturally demands a knowledge of the breadth of the Connecticut Valley onion market.

The grower would do well to supply his own bags and have them properly marked with his name and address as a guarantee of his willingness to stand back of his product. Harvest carefully, grade conscientiously, brand honestly and one has gone a great way towards insuring a satisfactory price.

3. Most growers are unable to store because they need immediate cash returns in order to pay existing debts. For such, co-operative selling associations would be helpful or some arrangement by which loans could be obtained by depositing warehouse receipts as collateral. Such receipts are now given by many cold-storage corporations as soon as products have been placed in their storages and, in many instances, loans are made on

such holdings. It would seem that the local storage men might issue these receipts to the growers whose onions are held in their warehouses.

4. The holding of onions in storages is generally advisable, but to do this with profit a knowledge of the available supply and general market conditions is absolutely essential.

5. To guide him in selling to the best advantage the grower should have more exact information of market conditions and prices. At present farmers sell more or less blindly. Newspapers, produce reports, market bulletins and trade-papers help, but they are not sufficiently accurate or definite to be of much real assistance to the farmer. Price quotations and market reports carefully compiled by State or Federal market bureaus should be made available to all growers.

But much of the advantage gained in this way will be lost to the farmers, because they cannot hope individually to learn everything about marketing and distribution. Moreover, a hundred farmers can hire a marketing expert to handle their products by organizing themselves into a growers' mutual marketing and purchasing agency, operated on a strictly co-operative basis.

The market demands of the producer dependable goods, packed uniformly and neatly, well graded and shipped regularly in sufficient quantities to meet the demand. These can hardly be met by the individual farmer and because they cannot be met the retailer and consumer naturally go to the various middlemen for their onions. Organization and co-operation among onion growers would help to solve many of the existing marketing problems. It would also assist in disposing of onions through the auction route.

6. The onion farmer should make more use of the various agencies which are in a position to assist him in an unprejudiced way to produce and market his products.

Some of the agencies are as follows: —

(1) The Federal Office of Markets, Washington, D. C. This office assisted the Texas growers in a very definite way during the season of 1915–16. About April 1, two men were stationed in Laredo and other points in Texas to report the movement and distribution of car-lots of onions. At the same time representatives were stationed in twenty or more cities of the United States where onions are shipped largely, to report the daily market conditions and prices. The information collected in these cities was telegraphed each night to Laredo, where it was compiled and distributed for the benefit of those interested.

One function of the office is to assemble market information and make it public in such a way that the distribution of the crop and the prevailing market price can be known by any one. Each individual shipper can guide his action accordingly, without making known to any one else the details of his business.

Recently the department extended this service to include the onions produced in the Connecticut Valley. Certainly, such information covering shipments, receipts and market prices of onions should be of great value, both to growers and dealers.

As a sample of the information disseminated, one of the bulletins issued by the United States Department of Agriculture to Connecticut Valley growers during the early fall of the 1916 onion season is reproduced below.

ONION SHIPMENTS August 24, 1916

Massachusetts, 6 (2 Boston); New York, 9; New Jersey, 7; Ohio, 4; Indiana, 3; California, 8; Washington, 10. *Previously unreported;* Aug. 20: California, 11.

TELEGRAPHIC REPORTS OF TODAY'S MARKET GIVING JOBBING PRICES (WHOLESALER TO JOBBER)

BOSTON: 2 Wash recd. Mkt steady dem moderate. Wash Walla Wallas Yellow Globes qual cond good 100# bags mostly $2.25. Conn Valley qual cond gen good 100# bags $2.25. Natives in bushel boxes $1.25–$1.35.

PHILADELPHIA: Mkt weak dem limited. Qual cond fair. 100# sacks Yellow Globes Ohios $2.25–$2.35. Ill 100# sacks Yellow Globes $2.60. Western bu Whites $1–$1.25 Picklers $1.50–$1.75. Jerseys bu hampers $1–$2. 3 N J arrived, 2 unloaded, 2 track. 3 Western arrived, 1 unloaded, 2 track. 1 Mass unloaded, 1 Penn track.

NEW YORK: Unloads 1 Iowa, 3 Ind, 1 Penn, 3 N J, 8 N Y, 1 Cal, 1 Unknown origin recd. Jerseys qual ordinary cond good dem slow bu hampers $1–$1.25 (yellows), Whites $.60–$1, Ohios and Ind qual cond gen good dem slow Strd crates Whites $1.10–$1.50 few sales 100# sacks Reds qual fine cond good dem good $2.50. N Y qual fair cond good dem slow bu hampers Reds $1–$1.25 Yellows $.75–$1.25 100# sacks Yellows $1.25–$2.40 100# sacks Reds $2–$2.37½, bu hampers Whites $.60–$.70. Washingtons qual cond fair overlarge dem slow 100# sacks $2–$2.25. Iowas qual cond good mkt dull dem slow 70# sacks Yellows $2 few sales. Long Islands qual cond good small 100# sacks Yellows $3.50

The Federal Office of Markets also issues many bulletins on marketing problems which may be had by addressing the Federal Office of Markets, Washington, D. C.

(2) The Massachusetts State Board of Agriculture, State House, Boston. This Board is vitally interested in the development of the agricultural resources of the Commonwealth, and is spending considerable time and money in disseminating useful agricultural information through lectures, demonstrations, reports, institutes and correspondence.

(3) The Massachusetts Agricultural College. The college, more especially through the Experiment Station and its Extension Service, is in a position to render valuable aid to Connecticut Valley farmers. The Experiment Station, especially concerned with specific problems of Massachusetts agriculture, stands ready to assist in every way possible, both in problems of production and distribution. Its various bulletins are free, and may be had by addressing the Director of the Experiment Station, Amherst, Mass.

The Extension Service, through its force of instructors, its extension schools, and its publications, is bringing assistance directly to the community and the producer. Address, Director of Extension Service, Amherst, Mass.

SUMMARY.

1. The commercial onion-growing areas of the United States are well defined. Data concerning crop conditions in these areas are valuable as market guides.

2. The Connecticut Valley by virtue of its rich soil and foreign labor supply is well adapted to onion growing.

3. In close proximity to the large eastern markets, and with excellent transportation facilities, onions can be readily marketed. Land suitable for onion growing is still available, and extension of the industry is possible whenever economic conditions warrant it.

4. Land values have steadily increased, so that good onion land sells for from $200 to $500 an acre, and rents at $35 to $50 an acre.

5. The Yellow Globe Danvers is the leading variety grown. Red onions are not grown extensively, because New York and the west can produce them more cheaply.

6. The cost of raising and lifting a bushel of onions in 1915 was approximately 35 cents; of topping, screening, bagging and hauling to shipping point 6.8 cents.

7. Onion growing on shares requires little capital, and many foreigners with limited means are engaging in the industry.

8. The average yield per acre is from 400 to 500 bushels.

9. While it is possible to crop certain parcels of land continuously with onions, it is not advisable. Some system of crop rotation should be practised more generally.

10. Most of the onions produced in the Connecticut Valley are seed onions. Set onions are raised at a greater expense, but, in years when the Texas crop is short, sets are a valuable crop.

11. Accurate crop reports from the Bermuda onion districts are a good index as to the quantity of sets Connecticut Valley growers should raise.

12. Onions not intended for storage should be fairly ripe when pulled. After pulling, care should be exercised to prevent rotting and injury from exposure to sunshine and rain.

13. Onions intended for storage should be pulled while still somewhat green and stored as soon as possible after the roots have dried a little.

14. Careful attention should be given to the screening and grading of onions.

15. The problems of marketing Connecticut Valley onions are more serious than the problems of production.

16. More than 75 per cent. of the Connecticut Valley onions are bought by local dealers who are also storage men. Very few are consigned to commission merchants.

17. Sales to local dealers and traveling buyers are advantageous in that the grower deals with the buyer in person and receives cash at the time of sale.

18. Selling onions directly from the field transfers the risks of holding from the producer to the buyer and turns the crop into immediately available cash.

19. Sales of onions direct to the retailer or consumer are necessarily few, because under present methods of distribution most car-lot shipments must be sold through wholesale distributing agencies.

20. The local storage capacity is approximately 600,000 bushels.

21. The quantity of onions held in local commercial storages in December does not show very marked variations from year to year.

22. The actual cost of storing in the valley is about 11 cents per 100 pounds.

23. The average seasonal shrinkage in local storages is approximately 10 per cent.

24. The charge for hired storage is from 23 to 25 cents per 100 pounds.

25. The shipping season for Connecticut Valley onions lasts from the middle of July to the beginning of May.

26. Onions are sold out of storage from December until May. The month of heaviest shipment is March.

27. Allowing liberally for overhead charges, shrinkage and extra handling storages are a profitable investment.

28. Cold-storage facilities for onions may be had in Boston and New York. Onions are seldom placed in these storages before March 1.

29. Practically all shipments are made in 100-pound bags. A carload contains 250 bags.

30. The primary shipping points for Connecticut Valley onions are the principal cities of the New England and Middle Atlantic States. In recent years a considerable quantity has been shipped to the South Atlantic States and Canada.

31. The three chief varieties for the New England markets are the Connecticut Valley, Egyptian and Texas Bermuda.

32. A year of exceptionally good prices is likely to be followed by one of large production and low prices.

33. The three-year average (1913–15) price to the farmer was about $1.14 for 100 pounds of onions, as compared with the average wholesale price for onions out of storage, which was about $2.20 per 100 pounds.

34. The retail price of onions is fixed largely by custom, varying little from 5 cents per pound.

BULLETIN No. 170 SEPTEMBER, 1916

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION.

SHADE TREES,

CHARACTERISTICS, ADAPTATION, DISEASES AND CARE.

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PUBLICATION OF THIS DOCUMENT
APPROVED BY THE
SUPERVISOR OF ADMINISTRATION.

BULLETIN No. 170.

DEPARTMENT OF BOTANY.

SHADE TREES, CHARACTERISTICS, ADAPTATION, DISEASES AND CARE.

BY GEORGE E. STONE.

INTRODUCTION.

The general interest in shade trees, particularly in the eastern States, well illustrated by the amount of money expended upon them and the many questions asked concerning their welfare, has created a demand for a brief, practical bulletin covering the various questions relative to shade trees and their management. Bulletin No. 125, issued in 1908 by the Massachusetts Agricultural Experiment Station and the Massachusetts Forestry Association, covered the subject in a general way, but the publication is now exhausted.

Shade trees add greatly to the desirability of a community as a place of residence, and their æsthetic value cannot be estimated in dollars and cents. It is no exaggeration to say that the complete destruction of all the trees and shrubbery would reduce the valuation of some cities and towns very materially.

Trees also possess a utilitarian value which is recognized by the courts, and for the careless destruction of street trees the abutter is entitled to compensation. A street tree adds value to real estate in the same way that a sidewalk or curbing does, but while the sidewalk and curbing may deteriorate, a tree increases in value for many years; for example, a tree originally costing $2 to set out may be worth $150 in sixty years, which is equivalent to 7½ per cent. compound interest on the investment.

Too much emphasis cannot be laid upon the care of shade trees. In common with crops they give the best results under cultivation, but unfortunately the best conditions do not always exist. Trees grow fairly well on lawns, however, especially when the lawn is occasionally fertilized. Conditions on congested streets are quite different. Many of the trees on our village greens, where often little attention is given to their care, show neglect and need of better treatment. In many places they have been growing for years in sod to which no fertilizer has been applied and a hay crop removed annually, and in such cases one year's use of a plow and harrow, together with manuring and some kind of cropping, would work wonders in restoring them.

In applying remedies to trees it is well to be on the conservative side, since it is a very easy matter to cause them serious injury. The different spraying mixtures, etc., recommended for trees are not always to be depended upon, and many trees are injured by their use; hence a word of caution is not out of place. Unfortunately, at the present time it is necessary to be on the watch for fake "tree doctors" who often do more damage to trees than good. This class of so-called "tree experts" has greatly increased within the last few years, and in some localities has become a nuisance. The "tree faker" is not only ignorant and incompetent, but is dishonest and a "divine right" fiend. There is another class of workers who may be ignorant, but honest; and still another class possessing some intelligent ideas as to tree work and a desire to be conscientious, but they fail to produce the best results. The men who possess sufficient technical knowledge and skill to undertake work on trees are comparatively rare, although fortunately there are a few competent firms and professional men who are capable of giving advice in regard to the treatment of trees.

The tree warden should be, and often is, a man of intelligence and common sense, and one to be called upon for advice pertaining to trees.

Requirements of Shade Trees.

As a rule, those trees should be planted which are known to thrive well in the particular environment under consideration. The fact that a tree does not grow naturally in one locality is no evidence that it will not thrive in some other, and it is well known that species of trees peculiar to wet places will grow in those inclined to be dry; but there is a limit to the adaptability of trees as regards their best growth and development which should be taken into consideration. A species naturally adapted to a wet environment is more likely to suffer from the effects of extreme meteorological conditions when planted in a dry situation than one normal to such places. The nature of the soil environment is, therefore, important; and there are many other factors which enter very largely into the problem of selection and planting of shade trees. Naturally there is a considerable difference of opinion in regard to what are the best trees to plant. It is important, therefore, to choose those species which are best adapted to the conditions under which they are to be grown, all trees having their weaknesses and defects, and perfection being no more common to trees than to the human race. The past decade has been characterized by extremely erratic conditions, such as unprecedented drought during the growing season, and severe winters, both of which have been responsible for so much deterioration of trees that the question of selecting resistant types has been a vexing one. Moreover, the presence of destructive insects and fungous pests, which heretofore have not been troublesome, has rendered the problem still more perplexing.

Some of the factors which enter into the problem of selecting species and varieties for shade trees are the following: —

Adaptability to Climatic Conditions.

One of the first requisites in selecting a tree for street planting is a knowledge of its climatic requirements. Many species of trees are likely to suffer from extreme meteorological conditions, and even species indigenous to a certain region may prove a failure when planted in a city or town as shade or street trees. There are also certain species which have their limitations as regards climate, such as some Japanese varieties, and in planting this should be taken into account. Under adaptability to climatic conditions is included the ability of a species to withstand the detrimental effects resulting from heat and cold, wind, snow and ice, atmosphere and soil moisture and light intensity.

Hardiness and Resistance.

Hardiness and resistance are the capacity of a species to withstand extremes of climate and the more or less abnormal and severe conditions of the particular environment in which it may be placed. These may arise in part from the peculiar atmospheric and soil conditions which are characteristic of congested settlements where the soil has been made from various types of refuse, or may be due to the presence of large manufacturing establishments.

Configuration and Conformity.

The shape or form of a species, as well as its conformity to its environment, is essential. Wide avenues demand different species from narrow avenues; and the habit of branching, root development, height, spread of the crown and general symmetry of the tree should be considered.

Longevity.

The age which a species is capable of attaining is important in its selection for planting, and while short-lived trees may have their use in certain places for temporary growth, a longer-lived variety should be selected for permanent effects. While the causes underlying senescence and rejuvenescence are hereditary in individuals, the life and usefulness of a tree may be prolonged by treatment, and its configuration greatly modified. Some trees, such as the apple, are readily rejuvenated, while others respond very poorly to treatment.

Rapidity of Growth.

The growth of trees in general is quite variable. Even individuals of the same species are different in this respect. Much also depends on environment in the growth of trees. The modern tendency in tree planting is to secure quick results; hence during recent years much use has been made on streets of the Carolina poplar and soft maples instead of the better and more slowly growing species, such as rock maples, elms and oaks. Excepting a few rapidly growing trees like the poplars and others, there is not much difference in the rapidity of growth of different species if they are given ideal conditions. While the production of quick growths is quite legitimate in planting, the idea of a permanent effect should not be lost sight of; and it is possible to accomplish both of these results by methods of planting.

Shade Production.

The amount of shade produced by any kind of tree depends on the shape of the crown and the density of the foliage. The more rapidly a tree grows the more quickly shade is secured. The shape of the crown varies with different species, but may be readily modified in such trees as the poplar by pruning. Shade constitutes the important feature in street trees, and is perhaps the most essential qualification of an ornamental tree.

Root Peculiarities or Habits.

The nature of the root development is an important factor in the selection of shade trees. Such trees as the maple and elm possess large, spreading root systems which are generally interfered with by street repairs, excavations, etc., while some other trees more restricted in their root development more often escape injury. The tendency of the roots of some trees to penetrate drainage and sewer pipes is an objectionable feature, as is also the upheaval of sidewalks, dislocation of curbings, etc., which result from the root development of certain species of street trees.

Neatness.

Much objection is often made to species like poplars, horse-chestnuts, etc., that produce litter, which requires frequent cleaning up. Some fruits, such as the mulberry, are mucilaginous and often become dangerous on sidewalks. Nut trees are also likely to be objectionable on residential streets because of the nature of their fruit and the liability of injury to the trees when it is gathered. It should also be mentioned that certain trees — such as the staminate form of Ailanthus — which emit disagreeable and irritating odors are undesirable.

Æsthetic Value.

The modern civic requirements in street planting demand not only the selection of healthy and vigorous trees and their general adaptation to the physical conditions surrounding them, but the consideration of beauty, taste and general arrangement as regards surroundings and conformity to an intelligent treatment, or, in other words, the æsthetic and landscape features. At the present time city streets are often provided with parkways which are planted with shrubbery and trees, and consequently both the nature of the species to be planted and the arrangement of the individual trees should be studied in order to have them conform with the general surroundings. This point of view of the matter is important and should not be lost sight of, since the æsthetic arrangement of streets and avenues adds to the value of adjoining estates in general.

Susceptibility to Insect Pests and Diseases.

Injurious fungi and insects are indigenous to every community, and many new pests are constantly being introduced, so that it is impossible to draw definite conclusions as regards immunity or susceptibility of any species of shade trees or ornamental shrubbery to those organisms. Judgment upon the probability of injury in any particular case must be based upon individual experience. There are scarcely any shade trees, however, which are not regularly affected by certain insects and fungi, and they are, moreover, subject to local and sporadic attacks. Trees which are exceptionally susceptible to insects, fungi and other injurious factors should be sparingly planted.

Commercial Importance.

Street trees are, as a rule, not planted for any commercial consideration, and the commercial idea should always be a secondary one. It happens, however, that sometimes the nature of the growth along country roadsides is such that thinning may advantageously be done, much good timber thus being obtained by the abutter; but this thinning should be done with discretion. There are also quite a few trees, such as the basswood and tulip, for example, and many shrubs, that are valuable as honey species, and their utilitarian value in this respect should not prevent their selection for planting. In European countries fruit trees are often planted along the country roadsides, where they not only serve ornamental purposes, but have a distinct commercial value in the production of fruit.

Street and Roadside Trees.

American Elm (*Ulmus americana*). — This is one of the most widely planted trees in New England, where it reaches its height of perfection. It is generally symmetrical in outline, attaining a good age, one hundred to three hundred years, and often large dimensions. The best developed types are majestic and more beautiful than any other tree known. According to Olmsted Brothers, landscape gardeners, "there is no other sort of tree which gives the effect of a lofty, over-arching canopy of foliage, which observation of village greens leads us to believe is the effect mostly to be desired." It is difficult for an elm to thrive on dry, gravelly soil, and when located in such situations it is inclined to be lanky, develops slowly, and is unhealthy in appearance. It is best suited to a fertile, more or less moist soil where fine sand and silts predominate, and is well adapted to lawns and roadsides, but not at all to mowings. The high branching habits of this tree render it the best type we have for streets on which there are numerous wires. In recent years it has become infested with such insects as the elm-leaf beetle, and most disastrously by the leopard moth. It has suffered more of late from the effect of drought than any other tree, and extreme cold has affected its root system to a considerable extent. These defects have been the means of discouraging its planting. The elm has a habit of occasionally shedding its leaves and twigs, and is sometimes affected by a leaf fungus (*Dothidella*).

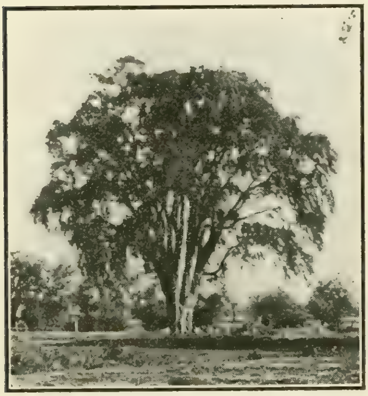

FIG. 1. — The Lancaster elm.

SLIPPERY ELM (*Ulmus fulva*). — Occasionally the slippery elm is planted by mistake for the American elm. It is, however, a much smaller and inferior tree.

ENGLISH ELM (*Ulmus campestris*). — This tree, which attains a large size, is a handsome species, and was formerly planted more extensively, at least in certain localities. It is, however, more susceptible to the elm-leaf beetle than our native species. Other elms which may be mentioned here are the Scotch elm (*U. montana*), which is occasionally seen; the Cork elm (*U. racemosa*), a tree of fairly good size with a corky bark and of slow growth; and the Japanese elm (*U. japonica*), a handsome, symmetrical tree of rapid growth, little known in America. Although affected to some extent by the elm-leaf beetle, this elm gives promise of becoming a valuable shade tree.

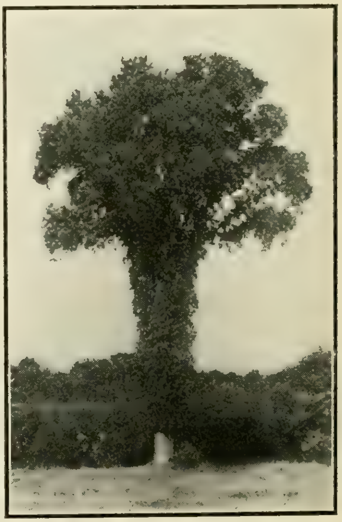

FIG. 2. — Type of feathered elm.

ROCK MAPLE (*Acer saccharum*). — The maples as a whole have been more extensively used for street planting than trees of any other group. The rock maple, like the elm, has been extensively employed as an ornamental tree; indeed, there is no species that has been used more widely for lawns and avenues than the rock maple. It is one of our handsomest trees, being characterized by unusual symmetry and dense foliage. It develops rapidly under good soil conditions, and occasionally will attain a diameter of 12 inches in fifteen or sixteen years. In some situations it grows to be an enormous tree, and quite often attains an age of one hundred and fifty years or more. The rock maple is sometimes affected with a leaf spot, and is more susceptible than any other tree to sun scorch and bronzing of the foliage. It is also quite susceptible to frost cracks. During the past five or six years this tree has suffered much from extreme drought, and as a result many staghead specimens are to be seen.

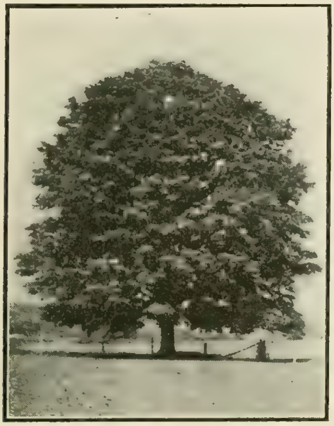

FIG. 3 — Rock maple growing in pasture.

White or Silver Maple (*Acer saccharinum*). — This species is not equal to the rock maple, either from the point of view of durability or of beauty, and it is too commonly disfigured by ice and winds. It grows very rapidly, and in southern New England, where magnificent specimens may occasionally be seen, it attains a great size. It is planted on avenues and lawns to a very large extent, but the drooping habit of its branches, together with its liability to injury, affect its value somewhat for street planting. In most situations its real value consists in its rapid growth and ability to produce quick shade effects. It is attacked by a leaf spot fungus (*Rhytisma*) which, however, does little harm.

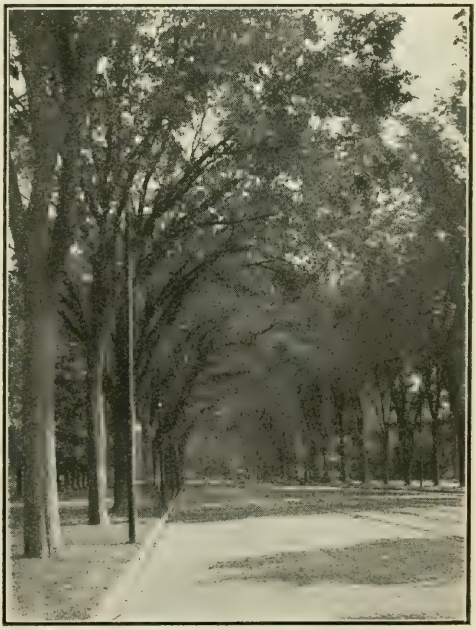

FIG. 4. — Avenue of elms planted close.

Red Maple (*Acer rubrum*). — The red maple is a tree of rapid growth, well adapted to swamps and fairly moist places. It has been planted quite extensively on streets, often, no doubt, in mistake for the rock maple. It develops large branches, usually rather low, which should be pruned at the time of transplanting. The foliage of the red maple is inferior to that of the rock maple both as regards color and density. This species has suffered much from drought and winterkilling of roots, which is characterized by a "staghead" condition. The leaves are often conspicuously spotted by the fungus *Rhytisma*.

NORWAY MAPLE (*Acer platanoides*). — The Norway maple is a wide-spreading tree, with large leaves which give a dense shade. It is well suited to lawn planting, and is highly regarded for streets and roadsides. The Norway maple is perhaps at the present day one of the most extensively planted street trees, especially in cities. It is a rapidly growing tree, and, at least when young, is very symmetrical and well adapted to city conditions. However, whether the Norway maple will in the long run prove equal to the rock maple as a shade tree under severe city conditions is a question. When planted in unfavorable locations it is sometimes badly affected with sun scald, and the small terminal branches sometimes winterkill and become affected with the cinnamon colored fungus *Nectria*.

WHITE OAK (*Quercus alba*). — This species is seldom planted as a street tree because of its slow growth. Its habits of branching are not always well adapted to streets, although it makes magnificent individual specimens for lawns and roadsides. It is occasionally affected by a leaf fungus (*Glœosporium*) and by various insects, and is one of the preferred food plants of the gypsy moth.

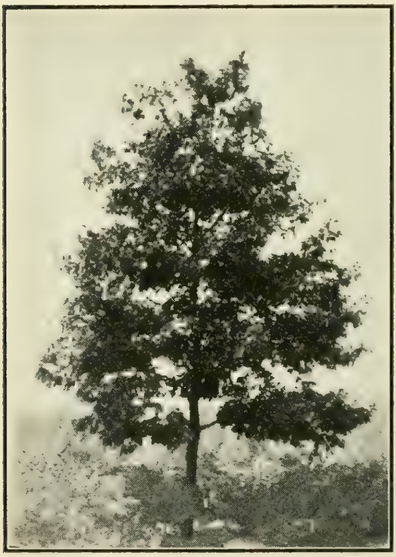
FIG. 5. — Specimen of red oak.

RED OAK (*Quercus rubra*). — In former years little consideration was given to the red oak as a street or ornamental tree, although recently it has received much well-deserved attention. At present it ranks among the first as a species possessing all the required qualifications for planting. The growth of the red oak is quite rapid; it is symmetrical and clean in appearance and exceptionally free from injury resulting from insects, fungi and other causes. It is adapted to a variety of soils, quite easily transplanted, and should be more extensively used as a street and country roadside tree.

BLACK OR YELLOW OAK (*Quercus velutina*). — This oak is often found associated with the red oak, but will tolerate much drier soils. It does possess, however, the qualifications of the former species, and is best adapted to country roadsides.

Scarlet Oak (*Quercus coccinea*). — The scarlet oak is one of the most beautiful oaks in New England. It is adapted to the driest and poorest of soils, often being associated with the black or yellow oak. It is a tree of slow growth, and on this account has been planted very sparingly in the past. Recently, however, it has come to be more appreciated. The beautiful scarlet foliage, characteristic of this tree in the fall, is much admired. It is well suited to dry, gravelly soil where other trees, such as the elm, will not thrive. In some cases it has been effectively alternated on country roadsides with some tree of rapid growth, as the Carolina poplar, the poplars being removed when the oaks have reached a fair size. The scarlet oak is worthy of much more attention as a shade tree than it has received, especially for suburban streets and country roadsides.

Pin Oak (*Quercus palustris*). — The pin oak has its northern limit in Massachusetts, and in the Connecticut valley, where it is found quite abundantly, it becomes a handsome tree. It naturally grows in rich, moist soil and often in water, and appears not to tolerate too dry conditions. The symmetrical, triangular or pyramidal shape of the crown and its drooping branches give it an individuality distinct from other trees. The growth characteristic of this tree in New England appears to be somewhat different from that further south, as is the case with most trees. In the north it appears to retain its youthful form longer than elsewhere. It should be planted in soil having a texture capable of holding moisture, and the addition of organic matter is advisable. Under desirable soil conditions the pin oak attains a diameter of 6 or 7 inches in nine or ten years. It is well adapted to narrow streets, and especially to lawns and parks. The characteristic drooping habit of its limbs necessitates careful and high pruning when planted on streets. The pin oak resembles the red oak in being relatively free from troubles induced by insects, fungi, etc., and may be considered one of our most promising shade trees.

Mossy Cup Oak (*Quercus macrocarpa*) and swamp white oak (*Quercus bicolor*) are sometimes planted on country roadsides. The latter, which makes slow growth, is adapted to wet places.

Basswood or American Linden (*Tilia americana*) is a native of New England, but is seldom planted on streets, although it is adapted to certain locations. It is a beautiful tree — with bright green foliage, graceful and symmetrical when young, but when planted too closely it loses its lower limbs and is inclined to early deterioration.

European Linden (*Tilia sp.*). — The linden has been much planted as a shade tree, and is a good tree when young and vigorous. The tree is not as a rule long lived, and it is often subject to sun scald and frost cracks from which it deteriorates rapidly. It is also likely to be affected with sooty mold, which follows the honeydew secretions of aphids. This materially affects the appearance of the tree. There are several species of linden under cultivation which possess distinctive characteristics, and these have been sadly confused by nurserymen. The two species most commonly planted are *T. vulgaris* and *T. platyphyllos.* According to H. J. Koehler,[1] *T. vulgaris* is one of the best trees to plant, while *T. platyphyllos* is one of the worst. Excellent types of lindens may be seen in the Arnold Arboretum, some of which will perhaps eventually prove superior to either of the above species.

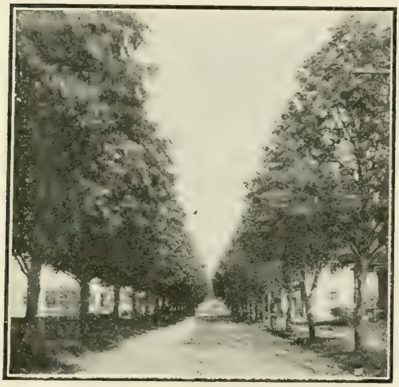

FIG. 6. — Avenue of lindens.

HORSE-CHESTNUT (*Œsculus hyppocastanum*). — The horse-chestnut, like the linden, was introduced from Europe, and has been much planted on streets. It grows rapidly, but it is not, as a rule, a long-lived tree. It is affected by a leaf-spot fungus (*Phyllosticta*), sometimes losing much of its foliage on this account, and often many of the twigs are winterkilled and affected with *Nectria.* It is also susceptible to sun scald and frost crack, and the amount of litter produced by the fruit is somewhat objectionable. The red-flowering horse-chestnut is occasionally planted and is preferred by many.

SYCAMORE (*Platanus occidentalis*). — Fine individual specimens of our native sycamore may often be seen on lawns and roadsides in New England, but it has been used in the past to a limited extent for avenue effects. The sycamore has a wide range, being confined in the north to river valleys. It naturally prefers a rich soil, and when transplanted under good conditions it attains a large size. The sycamore will endure any amount of pruning, and can be adapted to any street, even the busiest thoroughfares. Much more use is made of the sycamore than formerly, especially in cities, and the oriental species (*P. orientalis*) is also much employed. The sycamore is severely affected with a leaf-spot fungus (*Glœosporium*) which often causes serious defoliation. The younger twigs sometimes winterkill badly, but the tree will stand a great deal of hard usage and mutilation.

AILANTHUS (*Ailanthus glandulosa*). — The Ailanthus may be termed a "scavenger tree," as it will grow anywhere and will endure more trying conditions than any other tree. It is frequently found growing along railroad embankments, on dumping grounds, — in fact, no conditions seem too severe for it. It is used to some extent as a street tree, and excellent individual specimens may be seen here and there. Where quick effects are desired it is worthy of consideration. The Ailanthus, which is a native of China, is often termed the "tree of heaven," concerning which Dr. Asa Gray has well remarked that its blossoms are "redolent of anything but airs from heaven." To obviate the disagreeable odors arising from this species only the pistillate trees should be used for planting, the disagreeable odor being given off by the male or staminate flowers, which are often borne on separate trees. The Ailanthus apparently tolerates obnoxious atmospheric gases better than most other trees.

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[1] Landscape Architecture, July, 1915.

TULIP TREE (*Liriodendron tulipifera*). — This is an excellent tree for roadsides, although it is not very much planted. It is probably better suited to lawns and country streets than to the hard usage it might receive on city streets. The tulip is indigenous to different parts of New England. It is a difficult tree to transplant successfully, and this may account for its not having been more extensively employed. This species attains a large size, developing a large symmetrical crown with handsome foliage. It requires good, well-drained soil, and is best adapted to wide avenues provided with generous tree belts. The leaves sometimes become badly spotted from attacks of insects and fungi, but the loss in transplanting and its lack of adaptability to certain situations are the chief objections to its use as a street tree, at least in the north.

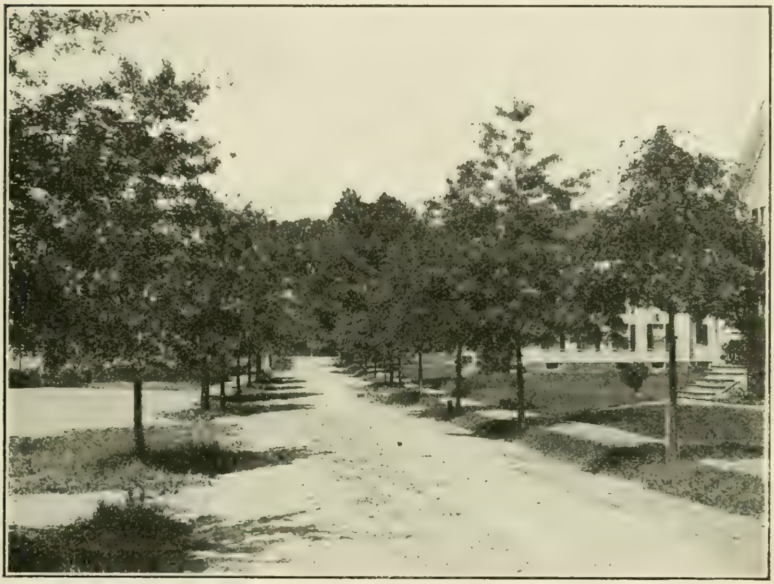

FIG. 7. — Avenue of pin oaks transplanted seven years in 40-foot avenue.

WHITE ASH (*Fraxinus americana*). — This ash is commonly seen on streets. It was formerly planted more extensively than at present. Our measurements of a number of white ash trees which had grown in good soil and which were twenty-two years old showed an average diameter of 16 inches, while others grown in dry, gravelly soil attained an average diameter of only 12 inches during the same time. The white ash develops a widespreading top, and is a fairly desirable shade tree, although in too dry locations it may become affected by borers and scale insects. It has suffered much in recent years from drought, winterkilling and in some locations from a rust (*Æcidium fraxini*). Other species of ashes, like the black ash, are occasionally planted accidentally for the white ash.

CUCUMBER TREE OR MAGNOLIA (*Magnolia acuminata*) has been highly recommended by some authorities for roadside planting. It has been employed extensively as an ornamental tree, but no attempt so far as we know has been made to utilize it as a street tree in the north.

SWEET GUM (*Liquidambar styraciflua*) is a native farther south, Massachusetts appearing to be a little too far north for its best development. At any rate we have observed no satisfactory growth of this species in this section. It is subject to winterkilling and frost cracks in the north.

GINKGO (*Ginkgo biloba*), a Japanese species, is occasionally seen on lawns, and forms a beautiful avenue on the agricultural grounds at Washington, D. C. Well-developed individual specimens of Ginkgo may be observed here and there in New England, and this tree has been used to some extent for street planting. It is adapted to a wide variety of soils, and is remarkably free from diseases. It develops a narrow cylindrical or conical crown, which adapts itself to narrow streets. This species is undoubtedly better adapted to planting farther south than in New England; nevertheless, it possesses many qualifications as a desirable street tree, and should be utilized for this purpose in suitable locations.

CAROLINA POPLAR (*Populus deltoides*), which is now quite extensively planted, is one of the most rapidly growing species, and is a valuable tree for producing quick effects. The Carolina poplar is especially useful to fill in between trees of slow growth but of more desirable types. Good avenues of this species may be seen about Boston in the metropolitan park system, where the trees have been cut back to form a compact head. This tree, however, is subject to various troubles, and is short lived. Two other native species of poplar, *i.e.*, *P. grandidentata* and *P. tremuloides*, are common, but have no value for planting.

BLACK OR ITALIAN POPLAR (*Populus nigra*). — This species has been planted somewhat as a lawn and avenue tree. It grows even more rapidly than the Carolina poplar, and possesses similar characteristics. It is affected by a rust (*Melampsora populina*) which sometimes causes much defoliation.

LOMBARDY POPLAR (*P. nigra* var. *italica*) has been planted sparingly for more than a century in New England, and has come into wider use of late. It is used somewhat on narrow avenues, although on account of its ascending and close-branching habit of growth it does not furnish much shade, and is, moreover, too stiff and conventional in appearance for most places. The white or silver-leaved poplar (*P. alba*) and the balm of Gilead (*P. candicans*) have been planted occasionally on streets and near dwellings for many years. The former, which is characterized by its silvery leaves, grows to a large, widespreading tree.

Black Locust (*Robinia pseudacacia*). — The black locust is one of our most rapidly growing trees, and while it is spontaneous here it is native farther south than New England. It adapts itself to severe conditions, and withstands obnoxious atmospheric gases better than any other tree, but it is so attacked by borers at times as to render its use as a street tree of little account. It is a valuable honey tree, and may be employed as a hedgerow or screen near dwellings, and near smelters and large manufacturing plants where noxious gases prevail.

Honey Locust (*Gleditschia triacanthos*) is a tree reaching large dimensions and provided with stout thorns. It is sometimes used in planting.

Chestnut (*Castanea dentata*) frequently grows profusely along roadsides and at times on lawns. It is not adapted to street planting on account of the litter accompanying fruiting, and its rapid destruction from the blight at present renders this species useless for any purpose.

Hackberry (*Celtis occidentalis*), which is closely related to our elm, is found sparingly in some of our river valleys, and occasionally met with on streets side by side with the elm. During recent years some have advised planting this tree instead of the elm, as it is said to be less susceptible to insects, particularly the elm-leaf beetle. It is a much inferior tree, however, to the elm.

Hardy Catalpa (*Catalpa speciosa*) is more at home in the west, although used here as an ornamental tree. With us it does not sustain its western reputation for growth, and according to our observations it has little or no value as a street tree in most northern sections.

Some of the willows are employed effectively for planting near marshes and low, swampy grounds. They afford protection to roadsides and are valuable as screens to unsightly places. The laurel-leaved or bay willow (*Salix pentandra*), which attains a height of 20 or 25 feet, is used on country roadsides and sometimes on lawns. It has dark green, glossy foliage. It is adapted to hedges and thrives well near the seashore. The weeping willow (*Salix babylonica*) and a few other forms are planted for ornamentation and shade-producing effects.

Fine individual specimens of the black walnut (*Juglans nigra*), a tree sparingly native in New England, may be seen on lawns, but according to our observations on the results of planting this species on roadsides it appears to be a failure as a shade tree.

Box elder (*Negundo aceroides*) is occasionally grown near dwellings, but is not a satisfactory street tree under New England conditions.

The various conifers may be used under suitable conditions, such as on country roadsides, and some use is made of them for this purpose. The white pine and Norway spruce are sometimes planted along roadsides, and are especially valuable as wind breaks. The European larch, Scotch and Austrian pines, as well as our superior red pine, may be employed advantageously for the same purpose. The shade produced by roadside planting is beneficial to a roadbed, as it prevents the rapid evaporation of water from the surface, and has a similar effect in this respect to some chemical road dressings in controlling dust. Moreover, a roadbed under such conditions retains its surface better than one constantly exposed to the sun, and there is less trouble from drifting snow.

Since new plant material is being constantly introduced into the United States from foreign countries there is a likelihood of some new and desirable species of shade trees becoming available in the future.

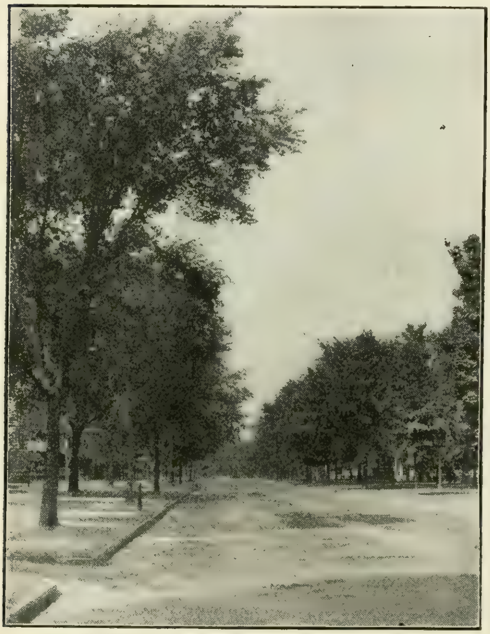

FIG. 8. — Street with ideal tree belt. (See Fig. 13.)

The large and unrivaled collection of trees to be seen in the Arnold Arboretum, Jamaica Plain, Mass., furnishes good examples for consideration. According to the most experienced planters the trees best suited for street purposes in New England are as follows: *elm, rock, white, red* and *Norway maples, red, scarlet* and *pin oaks, basswood, tulip tree, Ginkgo, cucumber tree, hackberry, English elm, horse-chestnut, sycamore* and *white ash.*

For wide avenues large species such as the *elm, rock* and *white maples, tulip tree, sycamore,* etc., are recommended; and for narrow streets the *pin oak, Norway maple, sweet gum, catalpa, Ginkgo* and *horse-chestnut.* For severe conditions the *English elm, horse-chestnut, linden* and *Ailanthus* are considered the most desirable species. No fixed rule, however, can be laid down as regards the use of the different species of trees for wide, medium or narrow streets, as different effects in planting are often sought. Indeed, one of the most serious defects in planting of all kinds is the lack of originality. Imitation in methods, the constant use of certain species and varieties, and the extreme conventional effects often produced become wearisome, while the marked diversity of Nature's planting, always resourceful in producing harmonious effects, never becomes tiresome. In general, however, the large type of shade tree, like the elm, maple and others, should be used on wide streets, and those having a more pyramidal type of crown are better suited for narrow avenues. In considering the problem of the selection of shade trees it should be borne in mind that there exists much variation in their habit of growth due to the conditions under which they are grown, and what may do well in one location will be more or less of a failure in another. There exists a marked variation in the growth of trees, even of the same species, in a restricted territory, and one can find much variation in their mode of development, such as habit of branching, size and color of leaves, height to which they grow, and age to which they attain, — in short, their general configuration. The elm grows quite differently in the north than in the south, and even in New England many specific types may be met which are characteristic of special localities. Hence, in order to secure the best type of elm trees for planting it would be well worth while to obtain them from localities which develop the best branching habits, such, for example, as the Berkshire region in Massachusetts. There are some species that are indigenous to the south which grow larger and do better in their native environment than in the north.

Such trees as the magnolia, catalpa, Kentucky coffee tree, box elder, persimmon and mock orange are much better adapted to the south than the north, and consequently are of much more value as ornamental trees in that section.

What shall we plant?

Perhaps the most perplexing question relating to shade trees, at least during the last decade, is "What shall we plant?" There has probably never been a period within the memory of living man during which such severe conditions for vegetation have prevailed, especially in the eastern States, as in the past few years. Meteorological records for many years back would undoubtedly fail to show similar conditions, and even if they did they would be of little value, owing to the fact that there are important factors other than those recorded by meteorological observations which greatly affect vegetation and its mode of development. The growth of trees themselves, as well as local variations in a restricted environment, constitute a record of general meteorological phenomena. Since trees live a century or more, these data are valuable.

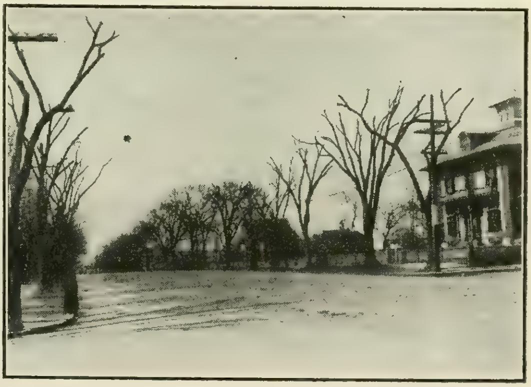

Fig. 9. — Showing deterioration of elms, largely due to the leopard moth.

Considering the amount of deterioration in trees during recent years many tree wardens and city foresters have been in a quandary as to what species to plant. But there is reason to believe that these severe conditions are past, and it may be a century before they occur again. One of our most valuable and beautiful species, *i.e.*, the elm, has been practically abandoned as a shade tree in some places owing to its rapid and general deterioration. There are many other species that have been affected in a similar manner to the elm, although perhaps not so seriously. Notwithstanding the fact that some trees have suffered particularly from various causes, we believe that these should still be utilized for planting, their æsthetic and other qualifications being such that they cannot be dispensed with. Moreover, affection by insects and fungous diseases must not always be considered too seriously in judging the value of a species, since control of many of them is possible with the use of modern methods. It should be borne in mind that many of the pests are secondary or are subservient to other causes.

The European cut-leaf birch, which has been dying off in wholesale fashion of late, is always associated with borers, which are considered a specific cause of the dying of this tree. Quite the reverse is true, however, as the borers are secondary to drought injury. In fact, every serious drought period affects the cut-leaf birch in this manner; the roots become dried out and the tree falls a prey to borers. Borers in trees may not always occur secondarily to some other cause, but it is extremely rare to find healthy trees affected with borers. As soon as a tree becomes slightly abnormal from any cause, infection follows. Even the slightest poisoning from gas or injury to the roots by drought or winterkilling is sufficient cause for weakening the trees, and borers and other insects follow as a secondary cause. There is no reason, however, why the European cut-leaf birch or other trees should fall a prey to borers if properly planted in a suitable soil and well supplied with water during drought periods, preferably by subirrigation methods.

The elm has suffered from elm-leaf beetle to some extent, although rarely is one found dying from this cause. Many elms have been practically ruined by the leopard moth. However, it can be stated as a general principle that weak trees, or those that are under more or less abnormal conditions, are more likely to be affected by insects and fungi than strong, healthy, vigorous ones. In our opinion this holds true for the elm-leaf beetle infestation, and some of our most careful observers regard the leopard moth as secondary to other causes. The so-called "chestnut blight" is held by some competent pathologists to be secondary to some other cause or deteriorating factors common to the chestnut. In support of this idea it is known that numerous chestnut trees have been dying the last few years, from New England to Tennessee, which are not and never have been affected with the blight fungus.

The most important lesson to be learned from the behavior of shade trees during the past years of trying experience is that we must give more attention to the specific requirements of the different species of shade trees, particularly as regards soil conditions. Species which cannot tolerate drought or the slightest soil desiccation should never be planted in sandy or gravelly soils possessing little water-retaining capacity; hence care should be taken in dry situations in eliminating those species which naturally grow in wet places. Neither should species that are adapted to dry soil be planted in wet places. The more extensive use of loam or soil containing a considerable amount of organic matter is needed in tree planting.

In conclusion it may be stated that the problems associated with tree planting during the last decade do not constitute a reliable criterion of the specific value of any species, since the same combination of conditions is not likely to occur in a century. We believe, therefore, that any one is justified in planting the much condemned elm, at least in country towns, where atmospheric conditions are much more favorable than in cities, and where the leopard moth is not so destructive.

Rapidity of Growth of Trees.

The variation in the growth of trees, due to the influence of many different factors, is quite marked, and even when trees of the same age are growing side by side great difference in the size and development are noticeable. A chestnut tree under certain conditions will attain a diameter of 3 feet in fifty-six years, while another may require one hundred and fifty years to reach a diameter of 18 inches. The average diameter of 20 white ash trees measured by us was 16 inches in twenty years; and Italian poplars will occasionally grow 26 inches in the same length of time. The Carolina poplar will reach a diameter of 30 inches in fifteen years, which almost equals the growth of the eucalyptus in California. We have observed pin oaks that grew 18 inches in diameter in twenty years. The average diameter of 16 elm trees thirty years old was 17 inches. In another instance a similar number of elm trees attained an average diameter of 20 inches 4 feet from the ground in forty years. Recent measurements have shown that the average diameter growth of the thirty-year-old elm trees for a period of seven years was 3 inches, while that of the forty-year-old trees during the same period was 4½ inches. It is not uncommon to find elms that have grown 3 feet in diameter in fifty years, or 4 feet in seventy years. An elm one hundred and thirty-one years old had a height of 110 feet, and a diameter of 6 feet at the base. On the other hand, many instances might be mentioned where trees have made very slow growth. Some elms, for example, showed a growth of only 11 inches in diameter in fifty years, and a white oak one hundred and thirty-two years old reached a diameter of 16 inches. Rock maples grow fairly rapidly in good soils, but we know of instances in which they have made only 6 or 8 inches growth in diameter in sixty years. Species accustomed to swamps, such as the white cedar and black spruce, grow quite slowly, the latter not growing more than 5 inches in diameter in seventy years.

To obtain the approximate growth of trees in any particular locality would require measurements of a very large number of specimens. The age of trees may be obtained by counting the annual rings of felled trees, or by cores taken from the trunk of living trees, while the age of conifers and others may be estimated by the number of internodes formed. There is often a wide difference of opinion as regards the age of living trees, as the total leaf area is seldom taken into consideration. Since trees acquire practically all their structural material from the air by means of the chemical processes going on in the leaves, it follows that those possessing a large total leaf area grow much faster than those with a smaller leaf area. A well-branched tree in the open will, therefore, grow six times as fast as one in the forest under crowded conditions. Consequently there is likely to occur much misconception regarding the age of living trees on account of the marked variation in their rate of growth under different conditions. The white pine, according to historical tradition, developed 6 feet in diameter and 250 feet in height in the New England primeval forest, and elms as street trees are known to have lived two hundred years. There are instances in Massachusetts where elms have lived to be three hundred years old. Many shade trees live to be one hundred and fifty years old and even more, and this age is not uncommon for forest

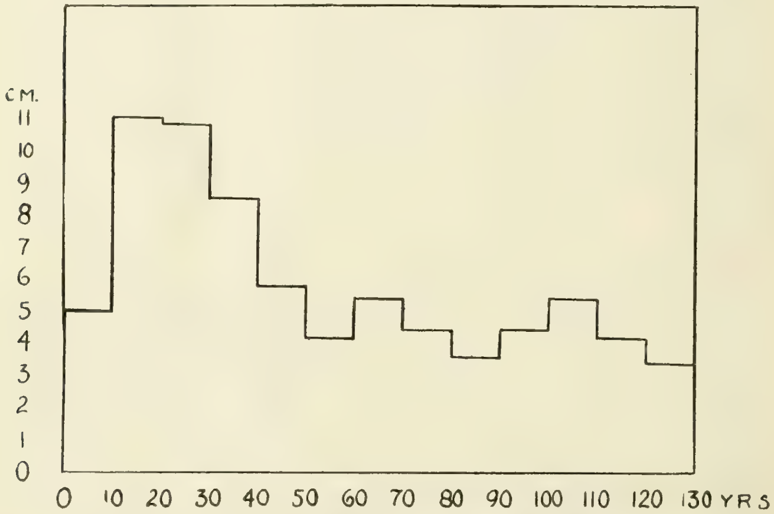

FIG. 10. — Grand period of growth (cross-section measurements) of an elm tree (*Ulmus americana* L.) in centimeters and decades. The maximum growth occurred between the tenth and thirtieth years, followed by a gradual decrease. From the nature of the curve we may conclude that if the tree had survived under normal conditions it was capable of developing for one hundred years more.

trees. Trees, however, do not grow with the same uniformity throughout their period of existence. At first they start in to grow more or less slowly, which is generally followed between the tenth and thirtieth year by the maximum development, this being followed throughout the remaining cycle by a gradual diminution in growth. (See Fig. 10.)

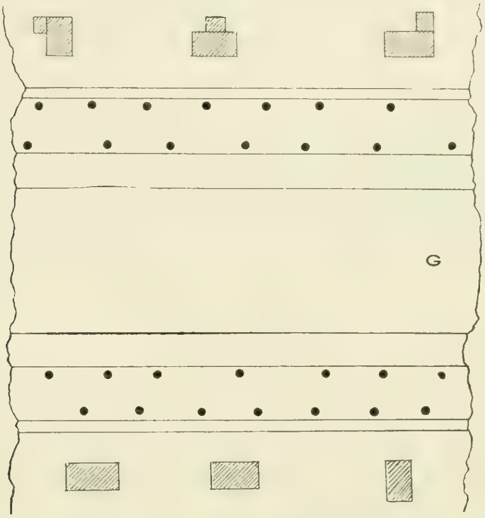

FIG. 11.—Plan of street at Hadley, Mass., approximately 300 feet wide, provided with two driveways with green (G) in center and generous tree belts.

The following list, showing the average growth of trees, represents approximately what a 3-inch sapling will develop into in twenty years.

	Inches.		Inches.
White maple,	21	Yellow locust,	14
American elm,	19	Hard maple,	13
Sycamore,	18	Horse-chestnut,	13
Tulip tree,	18	Honey locust,	13
Basswood,	17	Red oak,	13
Catalpa (*speciosa*),	16	Pin oak,	13
Red maple,	16	Scarlet oak,	13
Ailanthus,	16	White ash,	12
Cucumber tree,	15	White oak,	11
Chestnut,	14	Hackberry,	10

STREETS AND AVENUES.

The modern city streets are, as a rule, much better laid out for tree planting than the older ones, although there are some exceptions to this. In the Connecticut valley, where there is considerable level land, the early settlers showed remarkable judgment and taste in laying out their towns. Many of these old towns are arranged with exceptionally wide streets that from early times were systematically planted with shade trees. Some of these streets are 300 feet wide and have two rows of shade trees on either side of the street. On the other hand, many towns are poorly laid out, with no proper provision, or at any rate very poor provision, for planting trees.

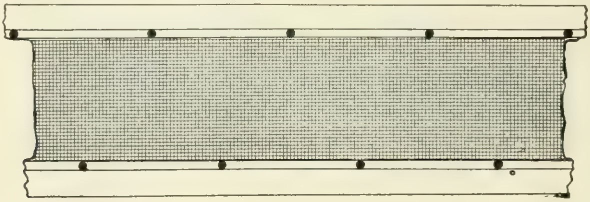

FIG. 12. — Narrow avenue, showing trees planted alternately about 45 feet apart.

Most towns will not accept a highway under 40 feet wide, which is narrow enough for tree planting; in fact, it would be much better if towns would not accept avenues less than 50 or 60 feet in width. Some of our modern cities, when laying out avenues, now make provision for a tree belt or a space between the curbing and the sidewalk where trees may be planted. This space should be at least 4 feet wide, and 20 or even 30 feet wide is better. A tree belt 2 or 3 feet wide is far better than none, since this allows some space for planting. In case the sidewalk comes next to the curbing, and a special tree belt is lacking, it is always advis-

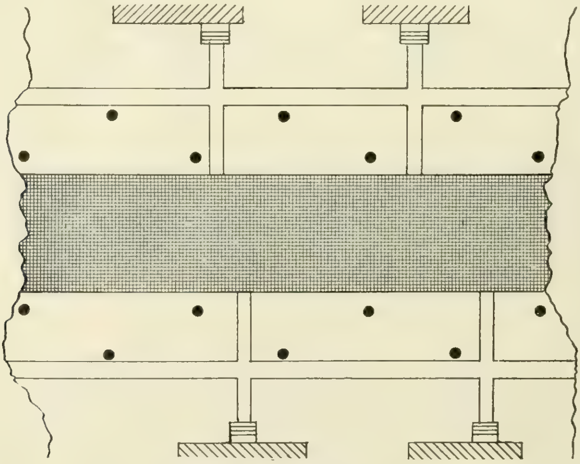

FIG. 13. — Plan of modern avenue provided with a 40-foot roadbed, 6-foot sidewalks, 23-foot tree belts, with alternating rows of trees 60 feet apart.

able to plant the trees near the abutter's line to protect them from horses, etc.; besides, the conditions for development are better here. When trees are planted too close to the sidewalk and curbing the roots interfere with them, and if the tree belt is narrow the roots are continually injuring the walks. In no case is it advisable to plant trees in the ditch, or even so close to the roadbeds that they are likely to be constantly scarred. Wide tree belts make it possible to alternate two rows of trees and secure more massive effects. A street having wide tree belts provided with good soil furnishes an excellent opportunity for tree growth and development, and with the installation of the best modern gas lines, sewer conduits, etc., there is no reason why trees should not flourish under these conditions. When the streets are narrow it is desirable, if conditions will permit, to plant alternately. This system allows much better opportunity for development of the trees.

Besides the tree belt, many of our modern cities reserve a space in the center of the street for a miniature parkway, to furnish a chance for the planting of trees and shrubs.

Much more attention should be given at the present day to the laying out of streets, and towns should be more careful about accepting too narrow highways. The present generation might learn much concerning street planning from the early settlers of our New England towns.

DISTANCE TO PLANT.

Opinions naturally differ in regard to the distance apart to plant trees. In fact, we must expect to find a diversity of opinion in all matters relating to the care and treatment of trees and shrubs owing to the variable conditions under which they grow; neither are the results sought for always the same.

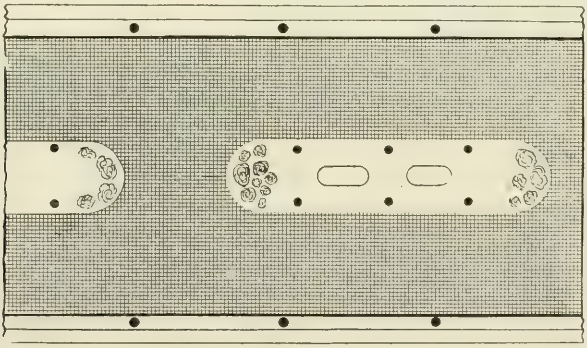

FIG. 14. — Plan of street with parkway and 6-foot tree belt.

If street trees are to be planted for their final individual effect they should be set far enough apart not to interfere with one another; but if the effect of the avenue as a whole is aimed at they can be planted closer together. What holds true in regard to trees is also true of shrubbery. Some gardeners plant masses of shrubbery together to get the effect of the whole, while others plant for the individual effects. Trees planted 20 or 25 feet apart will interfere in a few years, and if allowed to remain at this distance the individual effect of the tree is destroyed, although such close planting on an avenue is often effective.

In one city which we recall the elms were planted 25 to 30 feet apart many years ago, presumably with the intention of future thinning, but as no one apparently ever had the courage to do this, the trees have now so developed as to interfere, and as a result have become deformed through crowding. It is now too late to practice thinning on these streets. While their individual characteristics are destroyed by their restricted development, yet it must be confessed that the high Gothic arch effect produced by such close planting is effective.

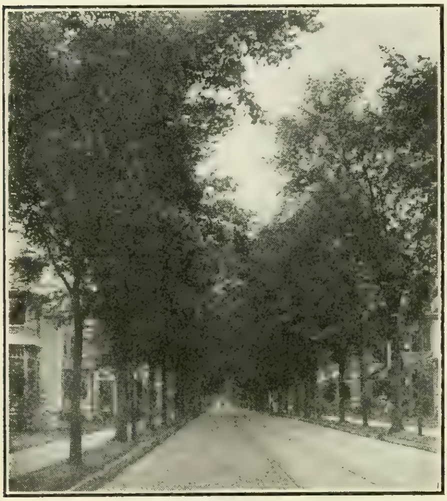

FIG. 15. — Street with tree belt, showing close planting.

When trees are planted very closely, every other one can eventually be taken out. The principal difficulty with this method is the courage required to do it; besides, in most places a hearing would have to be given for their removal which might meet with strong opposition. In one instance ash trees were planted in a row 25 feet apart. The limbs touched in twenty years, and later every other tree was removed, leaving the trees 50 feet apart. At their present rate of growth it will be some years before they interfere with one another.

The limbs of medium-sized rock maples planted 40 feet apart will interfere, as will those of larger trees of this species when planted 60 feet apart. A good average distance for planting most street trees, however, is 45 to 55 feet. Even 70 to 80 feet is not too far apart to plant elms in some localities, as this tree grows to a large size, with a wide spread of foliage, and we are familiar with specimens of rock maples growing along a roadside which have a spread of 75 feet. For smaller trees, such as the European linden, 30 feet apart is not bad. Many maples are set 50 feet apart, and in localities where the development is slow and they do not attain a large size, even 40 feet apart is suitable. When the growth of permanently planted species is slow, alternating trees of quick growth, like the Italian and Carolina poplars, is advisable, and when the more permanent trees have reached a fair height the poplars may be removed.

COUNTRY ROADSIDES.

One of the wisest provisions of the Massachusetts laws relative to shade trees is that trees and shrubs bordering country roadsides shall be protected by statutes similar to those in residential districts. Much of the senseless slashing of roadside shrubbery so long in vogue is now largely prevented. New England country roadsides are unsurpassed in beauty, and the miscellaneous character of trees and shrubs to be found growing along them is a source of great pleasure to tourists.

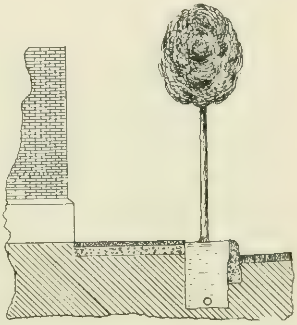

FIG. 16. — Illustrating method of growing trees on busy thoroughfares. The conventional type, such as the Oriental plane which tolerates severe annual pruning, is planted between the sidewalk and curbing in a rich loam 3 or 4 feet deep, provided with special subirrigation tile.

There are several ways of treating country roadsides. One of these methods is to maintain a regularly planted tree belt on a graded and neatly kept roadside, which results in a conventional effect. Another scheme consists in allowing the development of shrubbery and eliminating the tree growth which is often objectionable when crops are growing up to the highway. Or a system combining both shrubbery and trees may be employed, allowing the trees eventually to crowd out most of the shrubbery.

Most roadsides are lined with a miscellaneous growth of shrubbery and trees, located irregularly, which produce good effects, but when conventionality in the surroundings has been aimed at the well-kept roadside and tree belt are legitimate. However, there are roadsides on which no trees or shrubbery can be allowed, — for instance when the road runs through valuable farm land used for more or less intensive agricultural purposes. Trees absorb a great deal of moisture, and this factor and the shade produced interfere greatly with crop production.

For generations roadsides have been used for dumping grounds by certain misguided persons, and one of the objects of maintaining roadside shrubbery in its natural condition is to cover this extreme unsightliness from view. Unfortunately many think they are conferring a benefit on the public when they cut roadside shrubbery and leave it beside the road to decay. Roadside planting is Nature's planting, and is envied by the best landscape architects. It has the merit of intrinsic beauty; it is harmonious, no matter how heterogeneous the mass may be, and never becomes tiresome or monotonous like conventional planting. Many of the shrubs and vines which decorate roadsides are now used extensively by landscape gardeners in planting, and various species are very highly prized.

The native shrubbery consists of the various elderberries, Viburnums, honeysuckles, cornels or dogwoods, hawthorns, hollies, sumachs, azaleas, laurels, blueberries, etc. There are also such species as the chokecherries, witch-hazel, sassafras, alders, etc.

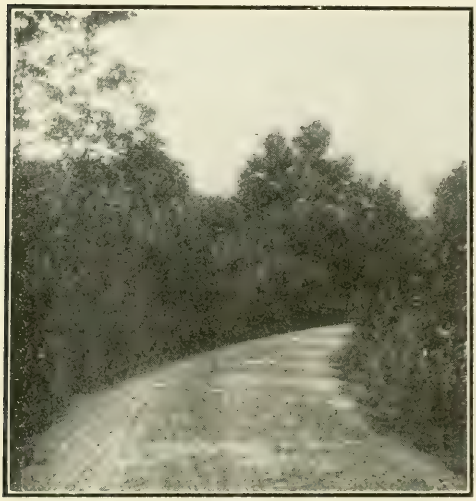

FIG. 17. — Country roadside, showing spontaneous growth of native species.

The most characteristic New England country roadside trees are the chestnut, various oaks and maples, hickories, ashes, pines, hemlock, elm, cherries, hornbeam, tupelo, birches and poplars. They are found growing in all sorts of combinations, mingled with different types of shrubbery, vines and herbaceous plants, with resulting effects quite unlike those obtained by artificial planting. Aside from the removal of briers and other growths too close to the roadbed, or the cutting out of the natural vegetation near abrupt curves where its presence constitutes an element of danger to traffic, or in cases where some legitimate scheme involving permanent improvement is concerned, roadside shrubbery should not be destroyed. There are, of course, occasions when the cutting of roadside shrubbery is desirable to improve the new growth which soon follows, but this should be done with discretion and care.

ROOT CHARACTERISTICS.

There are well-defined differences in the development of the root systems of shade trees. All seedlings develop what are termed primary and secondary root systems; the former are known as taproots and the latter as laterals. In certain species like the red cedar the taproot develops quite extensively. In young trees its function is relatively more important than in older ones; hence it is usually easier to transplant large pasture cedars than small ones, which are more dependent on the taproot.

The lateral root system in some trees is well developed, and those having this system are in general the easiest to handle. The elm, maple, hemlock, pine and others are easily transplanted with little loss because it is not difficult to obtain enough of the lateral root system to supply the tree. Some species, however, possessing lateral root systems appear to be dependent upon root fungi (*micorhiza*), which restricts them to particular soils and renders them sometimes difficult to get established in certain localities. Many plants, like the sumach and others, possess long, creeping lateral roots which must be taken up carefully to insure successful transplanting.

Depth of Roots.

Some idea of the depth to which roots extend may be had by examining excavations near trees, and also to some extent by plowing. Most elm and maple roots are confined within 2 feet of the surface, but in wet soil they are generally much nearer than this. The large roots of the European larch are very near the surface, and usually somewhat exposed. Pine and hemlock roots are frequently seen running on top of the ground, and in swamps, where trees often blow over, it may be observed that the entire root system is located within a few inches of the surface. Oak and chestnut roots do not appear to penetrate very far, as shown by the ease with which winds uproot the trees when growing even in ordinary soil. The maximum number of roots of most trees in ordinary soil is probably located between 1 foot and 18 inches below the surface.

Roots often penetrate soil to great depths, and when growing in gravel become flattened out in irregular shapes from growing around large pebbles. Apple tree roots have been known to grow through a mass of coarse gravel 8 feet to obtain water, and elm and rock maple roots will penetrate quite a distance to reach a water table. The roots of the common clover one year old have been known to descend to a depth of 8 feet; those of parsnip more than 13½ feet; and of lucerne, a leguminous plant, more than 20 feet. The roots of a leguminous tree growing in India have been traced to 69 feet below the surface without reaching their full length.

The distance to which roots extend laterally may generally be roughly determined by the spread of the crown. Practically all trees extend their roots beyond their foliage or branches. The Norway spruce and others, which have narrow crowns, do not have an extended lateral system. The maple and elm have well-developed root systems which extend to a considerable distance.

There is a correlation between the shape of the aerial portion of a plant and its root system. The leaves of root crops like radish, turnip and others are so placed on the stalk that they divert the rain toward the axis of the plant, or taproot. On the other hand, the apices of the leaves of many plants are deflected away from the axis, *i.e.*, toward the lateral or feeding roots. Most shade trees are noted for their large crowns, with the leaves pointing away from the trunk and directing the rain where it is most needed, whereas the soil near the trunk does not receive much water. This feature admirably illustrates biological adaptation.

Such trees as the balm of Gilead and Italian poplar possess extensive root systems. This is evident from the root suckers which may frequently be seen coming up quite a little distance beyond the spread of the branches, and many roots will grow in a horizontal direction to great distances. There is an authentic case of an elm whose roots were found in abundance 75 feet from the trunk, — just the height of the tree. In another case the roots of an elm were found obstructing drain tile which was 450 feet from the tree. The leading roots of a pear tree developed in 60 feet of a line of drain tile during five years measured 8,498 feet (1.61 miles); if smaller roots be included, the total length was about 2 miles. A squash grown in a greenhouse produced in a few weeks a total of 15 miles of root growth, or over 1,000 feet of roots per day.

Obstruction of Sewer Tile, etc., by the Roots of Trees.

The obstruction of sewer services and drain tile by tree roots has in some places become such a nuisance that steps have been taken in certain cities to obviate it. The elm is a troublesome tree in this respect, often completely filling land drain tile for long distances with roots, and putting the tile out of commission.

The Carolina poplar is a more troublesome tree, however. This causes so much damage to house sewer connections that its use for planting has been discontinued in some sections. The Carolina poplar is a tree of such rapid growth that an extensive root system is developed in a short time. Sewage appears to have an especial attraction for the roots of this tree. They seem to have no difficulty in penetrating even the cement joints of Akron tile, and when once in the tile the root development is remarkable. In one city as many as eighteen sewer services had to be taken up and repaired in one month the sections were so badly congested with roots of the Carolina poplar. Other tree roots occasionally enter tiles, cesspools and wells, but the Carolina poplar appears to be the greatest offender in this respect.

From the results of numerous experiments covering a period of years it is evident that roots can be kept from penetrating drain tile by properly packing the joints with chemically treated fibers, which destroy the delicate roots as they attempt to enter.[1]

BRANCHING CHARACTERISTICS.

There is considerable difference in the branching habits of trees. This must be understood before a tree can be developed along desirable lines. The red and Norway maples have a habit of sending out large branches or secondary leaders at more or less oblique angles, very close to the ground. If allowed to develop, these render the trees undesirable for street use; but if started right when young by pruning, such trees may be trained to meet the requirements of residential streets. However, if pruning is attempted when they are fairly well developed, great injury results, and the symmetry of the tree may never be entirely regained.

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[1] Mass. Agr. Expt. Sta. Rpt. 23, Pt. 2, p. 35 (1911).

The habit of the rock maple is to produce one or two strong vertical leaders, and its ultimate development is such that it seldom gives much trouble so far as pruning is concerned.

The branches of the pin oak are low and drooping. This objectionable feature detracts from the value of this tree for use on streets, but may be overcome by high pruning.

The branching habits of the elm, on the other hand, make it one of our most desirable shade trees, the branches invariably forming acute angles with one another. Elms oftentimes develop low, more or less horizontal branches, but these possess no permanent value and may subsequently be removed. The ideal mature elm offers no obstacles to street traffic, and even the wires of public service corporations seldom interfere with the branches.

On the other hand, evergreens, like the Norway spruce, branch to the ground, and for their best development they should never be placed where it is necessary to prune them, as cutting the lower limbs of the Norway spruce and most other conifers detracts greatly from the beauty of the trees.

Many trees, including some of the maples, birch, oak, chestnut and elm, and most shrubs, have a habit of suckering or sprouting from the roots. Much of the timber growth such as the chestnut is of this nature, and is termed "sprout growth." This growth is very common in woodlands and along roadsides which have been cut off. Trees originating from root suckers do not possess the value of those grown from seed, and consequently should not be used for transplanting. Stump growth may develop faster for the first few years than seedlings, but later growth is often slow. As the sprout growth reaches maturity it generally becomes involved with the stump, which ultimately decays, leaving an ugly cavity at the base of the tree. Most sprout growth shows abnormalities in the foliage the first few years, and it is likewise more susceptible to aphis. The extensive root system of the tree which nourishes it induces malnutrition or overfeeding characteristics which are pathological.

The formation of sprouts on the trunks and branches of trees is of great value in their restoration. Sprouts sometimes originate from the callus of wounds, and are quite serviceable in accelerating healing.

Soil Conditions, Texture, etc.

It requires only a glance at the trees of any particular region to observe their natural choice of environment. While this does not always mean that trees will not grow elsewhere with the same degree of vigor as in their natural habitat, — indeed the growth is often more vigorous, — they are very likely to prove less resistant to various troubles. One cannot be always certain, however, that, because a species is restricted to a particular location or habitat, it has realized its optimum condition for development. In some cases there is reason to believe that their choice may be determined by some minor inherent peculiarity common to the species, such as seed habit.

Some species of plants are confined to dry soils, while in other locations the same species grow in moist situations. In a botanical sense these are identical species, but they may possess such different physiological adaptations as to warrant the term "physiological species."

Soil texture plays an important rôle in the distribution and development of plants, and is inseparably associated with water-retaining capacity. Soil texture affects the color, size and thickness of the foliage, and also has an influence upon susceptibility and nonsusceptibility to certain troubles.

Even in limited areas trees possess different habits of growth, and soil texture is probably the most important contributory factor. For example, the elms in the eastern part of Massachusetts are different from those in the Connecticut valley. Those growing in the Housatonic valley differ from either, assuming a more vase-like form and being characterized by the development of a larger number of vertical leaders or branches. The greatest number of symmetrical elms and the best types of branching occur in this region.

The rock maples in the Connecticut valley are of a different type from those found elsewhere, growing larger and more luxuriantly. This region is characterized, also, by the occasional occurrence of a beautiful, dark-colored, densely foliaged form resembling the black maple, *Acer saccharum* var. *nigrum,* noticed farther west. Like the elm, much difference in the branching habits of the rock maple may be observed here and there which appears to be characteristic of certain localities.

There is, however, a wide diversity of conditions in nature under which trees may live and develop. The rock maple, oak and hickory appear to be at home on our rocky hillsides, while the basswood, canoe birch and beech are adapted to soil containing humus. The chestnut is confined largely to clay hills or "drumlins," where it has grown since time immemorial. The sycamore, pin oak, red maple, tupelo and swamp white oak are confined to low, moist soil; while the scarlet, red, white and yellow oaks, pitch pine, poplar, gray birch and red cedar prefer drier locations. The willows, Carolina poplar, red birch and hackberry are closely restricted to streams; and the white cedar, tamarack and black spruce to swamps. The white pine is quite generally distributed, and in New England it is adapted to a greater variety of conditions than any other tree in our flora.

Notwithstanding the wide diversity of conditions to which our native trees are subject, they can with care be made to thrive under different conditions. Rhododendrons may be grown successfully in dry soil having 2 or 3 feet of muck placed underneath, and trees adapted to moist places will develop well in poor soil if freely supplied with fine-textured loam.

The moisture content of a relatively dry soil may be greatly modified by the addition of organic matter, which increases the water-retaining capacity and makes the soil more suitable to swamp-loving species. But swamp trees that make excellent growth in dry soil need to be supplied with water during drought periods.

There are other factors than those of soil texture, water supply, etc., that influence the distribution of plants. The chemical composition of the soil affects the habitat of trees, and is capable of modifying to some extent their mode of growth. Many plants are restricted in their range owing to differences in the chemical composition of the soil. Certain species are practically confined to the seacoast, where the percentage of chlorine in the soil is greater than it is inland; but these species may be grown successfully elsewhere. The amount of humus in the soil affects the growth of trees materially. While 20 or 30 per cent. of organic matter was formerly contained in the upper strata of our soils, now not more than 2 to 5 per cent. may be found in a large portion of it. Organic matter has a vital effect not only on the physical properties of soils, but on their chemical and biological properties, influencing the development of *micorhiza* (beneficial root fungi) that are intimately associated with the roots of some of our shade trees. Soils also contain toxic elements that are often found in sufficient abundance to make it difficult to establish certain species in the desired location.

It is desirable in all cases when planting trees to give them conditions closely approximating their requirements as determined by their natural habitat. Elm trees often grow in swamps, as well as in dry and sandy soils, but both of these habitats produce poor specimens. The swamp tree is usually of inferior shape, and sandy soil as a rule produces a lank, spindling growth, with inferior foliage. Even the best type of elm, if planted under uncongenial conditions, will make poor development regardless of its inherent qualifications. The elm, therefore, should never be planted in dry, gravelly soil without being supplied with a large amount of good loam of the proper texture. The rock maple, on the other hand, will endure a dry soil much better than the elm, although if too dry borers may affect the tree. The scarlet and black oaks will thrive in such a soil.

In general, the texture of the soil in most towns is fairly well suited to the growth of a large variety of trees. The soils often lack organic matter, hence the application of loam is advantageous. On the other hand, some of our New England river valleys are particularly adapted to the growth of elms and maples, and the addition of loam in such cases is not so necessary.

Street trees are too often forced to exist under extremely unfavorable conditions; therefore they require different consideration from those more favorably located. Many city trees are planted in made soil, and some of the refuse found in these fillings is hardly adapted to tree growth. Such soils are, moreover, likely to be deficient in organic matter and plant food, and are often in such poor mechanical condition that the soil capillarity is of little account.

SOIL COVERS, LAWNS, MACADAM, ETC.

The nature of the soil cover surrounding trees is scarcely less important than that of the soil in which the roots are growing. We find trees growing under many different conditions: *e.g.*, lawns, mowings, cultivated fields, paved and macadamized roads, sidewalks, etc., and it is hardly necessary to point out that cultivation is much superior to all other conditions. The importance of tillage is scarcely appreciated in the case of ordinary crops, even by lifelong farmers. Stirring the soil, even without the use of fertilizers, has enormous influence on the growth of crops, and is also an important factor in the control of various tree pests, a thrifty tree being more resistant to infection. Cultivation not only aerates the soil, but breaks up the capillarity and conserves the moisture, — of great importance in dry soils.

Examples of the good effects of cultivation on shade trees may be seen in the many specimens growing luxuriantly in soil in which crops have been cultivated for years. Trees under these conditions branch freely and produce large leaves of a deep green color. Cultivation of the soil about trees for even one year has a decided effect.

Next to cultivation, lawn conditions are perhaps the best. The grass, which is constantly being mowed and left on the ground, acts as a mulch and conserves the moisture. Some of our best trees grow in pastures, where the conditions are often unfavorable to the growth of grass or where the grass is kept closely cropped by grazing. A mowing or hay field is one of the worst possible locations for a tree, the elm being particularly susceptible to the ill effects of such an environment. Measurements of elms growing on either side of a road, one series being under partial lawn and the other under partial mowing conditions, showed differences in their development. The average growth of these trees during a period of twenty-five years is as follows: those on the lawn side of the road had a circumference of 56 inches, while those on the other, or mowing, side were only 49 inches. In another case the average circumference of lawn trees was 37 inches, and that of the mowing trees, 26 inches. These trees, which had been growing under these conditions for many years, were of the same age, and were so located that the difference in light intensity cannot be considered a factor in their development.

The extensive use of various materials for paving roads can hardly have a beneficial influence on tree growth. In some cities a great many trees are found on streets paved with asphalt from one block front to another, allowing nothing but a small space around the trees unpaved. It is a question in such cases where the trees obtain their moisture, although they exist year after year, and make some growth. No doubt some water is obtained from catch basins and sewers; at any rate, moisture is usually found in the soil under the most impervious substance employed in paving, and during the most severe droughts trees on paved streets often suffer less from lack of water than others apparently more favorably located. This may possibly be explained by the fact that whatever moisture reaches the soil under these paved streets is to a certain extent conserved, the surface evaporation being less than where no pavements are found. The severity of the conditions to which trees are subjected when surrounded by pavements varies considerably, and when more or less water is allowed to leach through them the soil moisture conditions cannot be unfavorable. The more thoroughly a roadbed is sealed the more soil aeration must be affected. How largely this factor enters into the problem is unknown, but while trees do survive under extremely severe conditions, their length of life must be limited.

Excavations, Curbings and Sidewalks.

Remodeling and regrading streets are a frequent cause of injury to trees. In placing curbstones large roots are often cut, and in regrading streets so much soil is frequently removed that the base of the tree is left high in the air and the exposed root surfaces become injured by traffic. Besides these mechanical injuries, the exposed roots are likely to be injured from other causes such as winterkilling, sun scald, road oil, etc. If the roots are cut to any extent the tree deteriorates in value, and if grown under other unfavorable conditions it usually succumbs to a lingering death. Again, root mutilation too often takes place when sidewalks are being laid, and it is quite difficult to prevent it when the trees are large and have extensive root systems. The cement sidewalk with its deep foundation constitutes more of a menace to roots than a tar or brick walk, but if care is used in excavating, much root cutting may be prevented. The roots of trees located under a modern roadbed have little chance of remaining uninjured, with the sewers, water pipes, gas lines, telephone systems, electric wire and other conduits that are constantly being installed. Electric railways may also cause injury to trees in various ways. It is more injurious, of course, to the tree to cut the large roots close to the trunk than the small ones some distance from it. In widening a certain road a few years ago 4 or 5 feet of the banking adjoining a row of ash trees were removed, destroying a large number of the smaller roots on the west side of the trees, but this cutting had little or no noticeable effect upon the trees. They were young and vigorous, and on the east side the roots extended into cultivated ground, apparently soon making up for the loss on the roadside. Since the cutting of these roots, every other tree has been removed, and measurements of the rings of the stumps show that not the slightest retardation in growth had taken place following the operation. One fact should be remembered: mutilation of the root system is not so serious as that of the stems and branches, the former responding more quickly to the stimulus caused by mutilation. In transplanting young trees 80 to 95 per cent. of the essential part of the root system is usually destroyed, and even with a slight pruning of the top the tree usually survives when the work is properly done. Indeed, the cutting of the roots has been known to be beneficial, as, for instance, in the case of gas leaks in the street. Many cases are known to the writer where large trees have escaped gas poisoning owing to the fact that when the curbing was put in some of the larger roots leading towards the gas main were destroyed; therefore when leakage occurred there were no roots favorably located to absorb the poisonous substances.

The cutting of roots on vigorous trees is not so serious as cutting those of old trees. In the latter case judgment should be exercised as to root cutting.

Effects of Light and Shade.

Most plants are quite susceptible to light and shade. Those which require light are termed photophilic (light friendly), and those which thrive best in shade, photophobic (light shunning). Shade has an unfavorable effect on plants, causing a spindling growth and rendering them more susceptible to diseases. On the other hand, too much light is detrimental to certain species. The dense shade from street trees interferes at times with the growth of grass and shrubbery on lawns. Since there are relatively few varieties that are adapted to shade, it often becomes a problem as to what to plant in such locations. However, a glance at any native flora will give a hint of what is best adapted to shady places. Such wild species as clethera, rhododendron, hobblebush, leatherwood, moose and mountain maples, laurel and honeysuckle tolerate shade, and there are some exotic shrubs, such as *Ligustrum regelianum*, *Symphoricarpus vulgaris*, *Xanthorrhiza apiifolia*, etc., and vines like *Euonymus radicans* and *Vinca minor*, that are adapted to shade.

Notwithstanding the fact that shade is natural to some species, they develop a less spindling growth in light. Shade trees require light; hence for their best development they should be planted far enough apart to prevent interference and spindling growth. The effect of shade on trees when growing thickly together is a dying of the lower branches, inducing growth in height at the expense of spread of the crown and growth in diameter.

The variation in light intensity differs, as is well known, during the year. Light intensity is also variable in different localities, and there are definite variations that occur in light intensity during the day which are more pronounced at some seasons of the year than at others. The difference in the amount of sunshine peculiar to any region is not dependent on latitude but on other conditions. For example, the number of hours of total sunshine occurring during the year at Boston, Mass., is 2,493; Cleveland, Ohio, 2,075; Chicago, Ill., 2,616; Milwaukee, Wis., 1,865; Seattle, Wash., 1,973; Elkins, W. Va., 1,737; Phoenix, Ariz., 3,742, and New Orleans, La., 2,378. These marked variations in the number of hours of sunshine show that latitude does not necessarily constitute an important factor in determining light conditions. The amount of possible sunshine, according to the United States meterological observatories, varies from 37 to 84 per cent. Variations in light intensity or number of hours of sunshine are correlated with growth and development of vegetation, although temperature is very important too.

Morning light is more intense that that of the afternoon, and this difference exerts an influence upon the growth of trees. Measurements of a large number of tree stumps ranging from ninety-five to two hundred and twenty years old showed 17 per cent. more growth of the radii on the east side than on the west, and the radii measurements attained from the stumps of a row of ash trees running north and south were 24 per cent. greater on the east than west side. Two rows of trees bordering either side of a road running approximately east and west showed a difference of 11 per cent. in their circumference growth 4 feet from the ground, during a period of seven or eight years, in favor of the south row. Daily measurements of light made by us for one year showed an average difference of 10 per cent. in favor of morning conditions. Since photosynthesis or carbon assimilation is proportionate to light intensity, and growth is in proportion to photosynthesis, there naturally follows a greater growth on the east than on the west sides of trees, and the same holds true for the east and west slopes of high elevation. The light conditions at high elevations are more intense than low elevations, and the difference may equal 25 per cent. more or less, depending upon the altitude and other conditions.

Light is an important factor in the process of photosynthesis or carbon assimilation in leaves, about 95 per cent. of the structural material of the tree being obtained by this process. Light inhibits growth and stimulates the formation of mechanical and resistant tissue; on the other hand, darkness or lack of light stimulates growth. Light affects the size, color and texture of the foliage, and, in fact, the whole configuration of the organism.

Since morning light conditions are better than those in the afternoon it is well to set trees with their poorest developed sides towards the southeast, as they will become more favorably exposed to light conditions; hence they will develop more rapidly on this side. Moreover, an avenue of trees located on the east and south sides of a road will develop more rapidly than those on the west and north sides, and trees and crops located on the east side of a hill will develop more rapidly than those located on the west side. An east exposure is therefore much better for the rapid development of an orchard than a west exposure, and the same holds true for different crops and shade trees.

TRANSPLANTING.

Too little attention is given to the details of transplanting. It is quite essential that soil conditions should be suitable for the growth of the particular species of tree planted, and in the selection of material for planting there is great need of more care. A large amount of poor material is constantly being used, besides which, injudicious use of the knife and pruning shears maims many trees for life. Trees 6 to 8 feet high are usually too small for street planting, not being so well adapted to street conditions as larger ones ranging from 1½ to 3 or 4 inches in diameter. Moreover, by using larger trees one can obtain a better idea of their future development and configuration.

The life cycles of trees are by no means identical even in the same species. The conditions which a certain species seems to require at one period of its existence are less suitable for another period, especially as regards soil requirements for root development, older trees appearing to tolerate certain conditions better than younger ones. Young trees 5 to 6 feet high will often fail to grow for some years after transplanting under the poor conditions often prevailing on streets, while larger ones will start immediately to grow.

Much more attention should be given to the type of tree transplanted than is generally given. The same species varies greatly in different localities. Lopsided elms should be avoided, and only those selected which possess a habit of growth calculated to produce a desirable type. It is worth while to secure elms from those localities where the most perfect types abound.

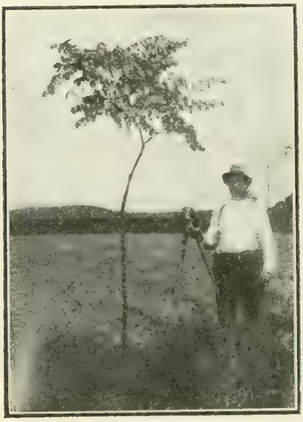

FIG. 18. — A State highway specimen of elm worthless for future development.

In localities where much desirable native material exists this can be used to advantage for street planting, and if carefully handled it will prove successful. Native material, or that gathered from the fields, however, is much improved by nursery conditions, and two or three years under such conditions are desirable when utilizing native stock.

Most competent authorities recommend planting a few trees well rather than many poorly, and when one recalls the large amount of poor planting seen around dwellings, and the weak-looking specimens of trees and shrubs, this advice will appear pertinent.

Town funds[1] do not always allow the appropriation of a large sum of money for transplanting trees, and one must do the best he can with the conditions under which he has to labor. Special attention, therefore, should be given to the adaptability of certain species to the conditions at hand, since the cost of extensive preparation and soil modification is too often beyond the funds allowed for this purpose. The advice given by Olmsted Brothers, landscape architects, in one of their reports, regarding the planting of elms, is to the point: —

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[1] During the year 1914, 12,498 trees were planted by tree wardens in 58 cities and towns in Massachusetts.

It would be better to prepare tree beds 2 to 3 feet deep and 20 to 30 feet square, filled with good loamy soil where the present ground is dry and sandy gravel, even if the expense of doing so would be so great that only one tree a year could be planted.

Few trees, however, outside of those planted in the Arnold Arboretum and on a few private estates receive any such treatment. It must be borne in mind in planting that shade trees are always under more or less disadvantageous conditions as regards atmosphere and soil. Hence it is of the greatest importance that they should be aided as much as possible, and the time is not far distant when much more specific methods must be employed in the planting of street trees in thickly settled communities. Even at the present time, where ideal conditions are sought much more money is spent in preparation for transplanting than in purchase of the trees. The majority of street trees which are planted are not supplied with loam or placed in holes over 2 or 3 feet wide and 15 inches deep, and some of them are given space only large enough to contain their roots. Loosening up the soil to a considerable depth is very important, as shown by the results of the use of dynamite in the preparation of soil for transplanting. A hole 5 to 6 feet wide by 20 inches deep in any case should be the smallest used, and it should be as much larger as can be afforded.

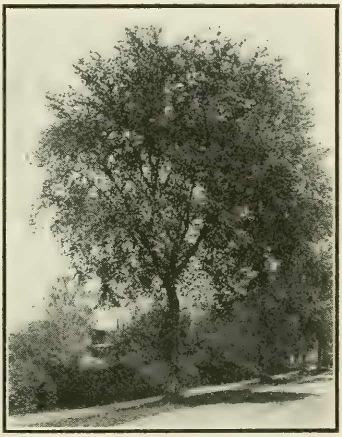

FIG. 19. — Elm severely cut back when transplanted. This has destroyed its natural symmetry.

When digging up young trees the roots should be preserved as much as possible, and the more earth taken up with the roots the better. The roots should not be exposed to sun and wind, and if possible should be kept covered and moist. For this purpose damp straw, bagging or sphagnum moss may be used.

It is usually the practice to place the best side of the tree toward the north and the poorest toward the south, since the light conditions on the south side are better, and naturally better growth results. It is also advisable to lean a tree toward the direction of the prevailing winds, and if these are strong enough to interfere with the growth of the tree it should be fastened to a strong stake. Trees obtained from the field where they have been growing close together have long, slender shafts and are top-heavy. When such trees are planted in windy situations it is necessary to support them by stakes.

When the ground is prepared for planting, the injured roots should be recut so that healing may take place, and before being covered they should be properly arranged in the soil. According to good authorities trees should never be planted more than two or three inches deeper than they originally grew, and too deep planting often causes their death. It is more convenient for two men to set out a tree than one, as one can hold the tree in the proper position while the other is filling the soil in around the roots.

The top soil, if of good quality, may be used, but it is better to discard the poorer subsoil and replace it with loam. Much depends, however, upon the nature of the subsoil and whether the species is adapted to grow in it. In any planting the best soil should be placed at the bottom of the hole or under the roots, and the sod when properly pulverized may be used, care being taken not to interfere too much with the soil capillarity. The poorer soil which covers the roots may be enriched and its texture improved by working in manure or other organic matter. Manure, however, should be sparingly used and thoroughly incorporated with the loam, care being taken not to bring it in too close contact with the roots. Towns and cities which do much transplanting might make good use of composted street cleanings; and if land were available for a small nursery, it could be used to good advantage by tree wardens and foresters.

When a tree is being set out the soil about the roots should be well tamped. Many people apply water to the roots at the time of transplanting, and if the season is an unusually dry one the watering may be repeated occasionally. But persistent watering is injurious, and young trees are sometimes killed in this way. If the soil around the roots is well tamped when the trees are set out it is not essential that water should be applied at all, and it may even be injurious by washing the soil from the roots and leaving air spaces. One of the most essential features in transplanting is to secure as nearly as possible normal conditions of the soil about the roots. It may be mentioned here that watering large trees near their trunks is not a wise practice, since the feeding roots are quite a distance from the tree. One would suppose that an elementary knowledge of tree growth would discourage such a course, although it is possible, by constant watering and cultivation, to encourage the formation of roots at the base of the tree.

After the tree is set out a mulching of hay, straw or horse manure containing considerable straw may be used to help conserve the moisture in the soil and to keep down the grass and weeds which rob the soil of its moisture and food.

Transplanted trees require a certain amount of pruning to accommodate the leaf and root systems to each other, and it is usually necessary to cut back the branches to meet these requirements. (See Pruning.)

There are differences of opinion in regard to methods of transplanting trees, and undoubtedly more than one method may be used. Opinions also differ in regard to the best time of year for transplanting, but it may be said that most persons prefer the spring to the fall. We are of the opinion that it is not advisable to plant too small trees, preferring elms and maples $2\frac{1}{2}$ to 4 or 6 inches in diameter, since they take hold of the soil better.

At the present day many very large trees and shrubs are being transplanted successfully. Special machines have been designed for use in this work. The Hicks Tree Mover, designed by Mr. Isaac Hicks of Westbury Station, Nassau County, N. Y., is extensively used, and Mr. Hicks has achieved remarkable results in handling very large specimens of trees and shrubs. These tree movers are expensive, however, and for trees 6 to 10 inches in diameter a pair of high, heavy truck wheels, with some simple improvised arrangement, may be adapted. At the present time many individuals are willing to pay a good price for large trees, for which tree movers are admirably adapted and should be more extensively used.

A general tendency has been to plant street trees rather closely, with the idea in some cases of cutting every other one when it should become necessary. The courage to do this when the time comes is often unfortunately lacking, however, and the trees are allowed to grow and crowd one another until it becomes too late to thin them out.

The loss from transplanting need not be great, although there is a great deal of difference regarding species in this respect. During a normal season the loss from transplanting need not exceed 2 or 3 per cent., and sometimes 100 trees from 100 will live. During severe drought periods a greater loss is expected, and even 50 per cent. loss in a good season occasionally occurs from poor planting. Such trees as the tulip tree and tupelo are naturally difficult to transplant with success, and a considerable loss with such species is anticipated.

Tree Surgery.

The term "tree surgery" is a legitimate one to use in describing modern methods of treating trees, as they are similar to those used in human and animal surgery, *i.e.*, the treatment of trees is based upon aseptic and antiseptic methods.[1] In the same manner that modern surgery is successful in correcting deformities, performing operations, etc., so a young and vigorous, although often imperfect, tree may be improved and rendered more valuable by the use of the same methods. While old and decrepit trees are often treated to extend their period of usefulness, it should be borne in mind that it is more desirable to care for the younger, more promising trees, and it is only too apparent that if more attention had been given to the care of old trees at the proper time they would never be in the condition in which we often find them.

Unlike the surgeon, who has no choice of subjects, the tree expert can select his individuals at the start and eliminate the imperfect specimens, although in the process of development trees need constant attention. It is desirable that antiseptic methods of treatment following pruning, mechanical injuries, etc., shall be adopted.

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[1] Some prefer the term "tree repair work" to that of "tree surgery" on the ground that the work is of a much cruder type than that generally recognized as "surgery." There are, however, many instances where as much skill and knowledge are required in this work as in animal surgery.

Pruning.

Besides the necessary pruning at the time of transplanting, the removal of dangerous dead wood and branches every two or three years is essential. In the case of street trees the lower branches frequently need removing or lightening up. When limbs are so close as to interfere, thinning out is necessary to prevent their injuring one another; but this thinning may be overdone so as to affect the beauty of the tree. Some make a practice of thinning and shaping trees when young, thus preventing too much thinning when the tree reaches maturity. The amount of dead wood annually produced in trees is quite large, and it costs about as much to dispose of it as it does to prune it away.

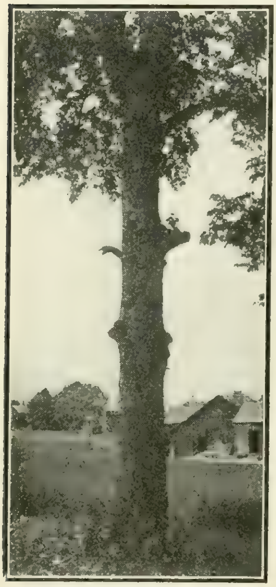

FIG. 20. — Specimen showing poor pruning. Note the long stubs.

In towns a distance of 10 or 12 feet or more may be left between the roadway and the lowest limbs, but in cities the nature and amount of traffic necessitate higher pruning. When street trees are growing close together high pruning is often necessary in order to let in sufficient sunlight, and when different types of trees are planted together, such as maples and elms, the pruning is often high in order that the high canopy or Gothic arch effect formed by the elm trees may not be destroyed. If a more or less symmetrical type in individual specimens is desired, the removal of certain limbs often changes the contour of the trees. We do not believe it desirable to prune the feathery growths often found on the trunks of elms, as they are apparently protective in nature; moreover, in our opinion they add to the beauty of the tree, taking away much of its conventional appearance.

As a rule, the limbs of vigorous maple trees will droop a foot or more a year owing to their increased weight, and in a short time they become too low. Limbs over a sidewalk may be left lower than over roadways. During rain and sleet storms limbs are heavily weighted and often give trouble when too near the ground.

On country roadsides pruning should be high enough so that the limbs will not interfere with hay and wood traffic. All limbs should be cut as close as possible to the tree, and cuts over 1½ to 2 inches in diameter should be treated antiseptically to prevent decay. Strictly horizontal cuts should never be left. They retain water so that rot is likely to result, and the cleaner the cut the better it will heal. There is, moreover, less chance for subsequent rotting.

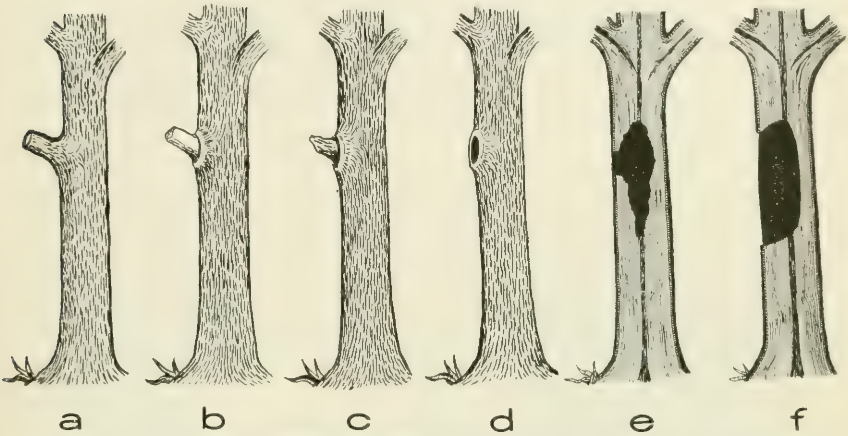

FIG. 21. — Showing the evolution of a cavity and method of treating it: (*a*) long stub left from pruning; (*b*) beginning of decay; (*c*) more advanced stage; (*d*) cavity formed in the wood; (*e*) longitudinal section of the trunk showing cavity; (*f*) cavity cleaned out and ready for orifice covering.

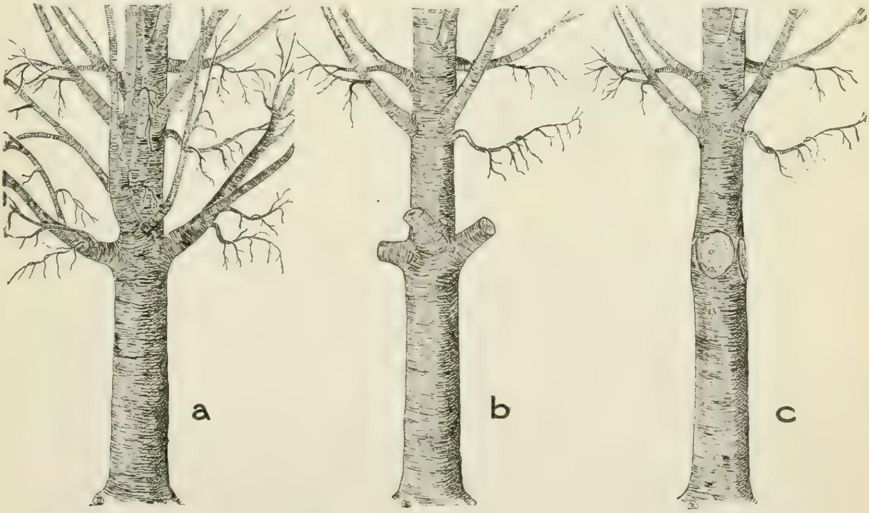

FIG. 22. — Method of pruning large limbs: (*a*) tree before pruning; (*b*) showing relative distance of first cut from the tree trunk; (*c*) the same with limbs cut close and the scars finished with mallet and chisel.

Many of the cavities in trees are caused by leaving long stubs on the trunk of the tree, which become infected and disintegrated, the decay following back into the heart of the tree. (See Fig. 21.) It is therefore essential that close pruning and antiseptic treatment of the wounds should be practiced in order to prevent this decay. The plastic materials in a tree will not follow up a long stump and form a callus unless there are some branches left upon it which bear leaves, and even then healing is most likely to take place only close to the living branch of the stump.

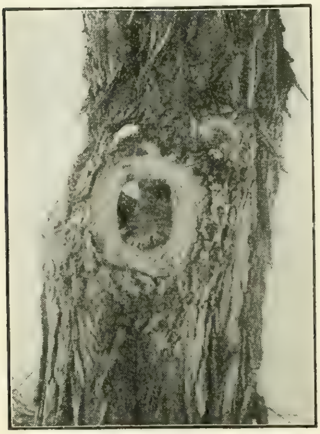

Fig. 23. — Formation of a cavity in tree caused by the removal of a large limb, and wound not properly cared for.

Two or more cuts should be made when pruning practically all limbs to prevent peeling, and on limbs of any size it is necessary to make the incision on the under side for the same reason. (See Fig. 22.) After removing the limbs with a saw, a mallet and chisel may be used to smooth up the cut surface. This induces a better callus growth. It is well to prune carefully at the time of transplanting, when all street trees should be trimmed to a height of 8 or 10 feet or more. It is usually necessary at this time to prune for the purpose of balancing the root and branch system, and when this is done some of the less desirable branches may be sacrificed, and those remaining may be cut back to some extent, if necessary. However, a great deal of unwise and careless pruning of nursery stock and young trees is done, and many specimens are ruined in this way. Tree pruning shears should not be used in a haphazard manner, and a distinct idea of the object in view should be borne in mind. Moreover, species differ greatly in their response to mutilation, and what may prove of little consequence to one may be quite injurious to another.

The practice of topping trees is injurious, and should never be resorted to except in special cases. All of the reserve material in the tree is stored in the roots, stem and branches, and in a transplanted tree this is sufficient to develop the foliage. It is necessary that a young transplanted tree should have a certain amount of foliage for growth and development, since the rapidity of growth is dependent upon leaf development.

The type of trees termed "bean poles," having the tops so cut away that there are no limbs left, is not suited, therefore, to transplanting. Trees like the willow will survive any amount of mutilation, but elms, maples and others must be handled more carefully to obtain the best results. Pruning has a marked effect on the conformation of trees. Pruning the branches or secondary organs directs the energies of growth to the trunk, whereas topping, or the destruction of the leader, has the reverse effect. Continual pruning of the lower branches induces the tree to grow taller than it otherwise would, and in some locations is advantageous to the tree. Topping is destructive to the formation of typical crowns in such trees as the elm, hornbeam, etc., whereas in other trees, like the Carolina poplar, topping or pollarding has a tendency to thicken them up and make them more desirable shade trees. The configuration of the crowns of maple trees is modified to some extent by topping them when they are young. This modification is manifested by the more vertical growth of the branches, thus producing a more narrow crown.

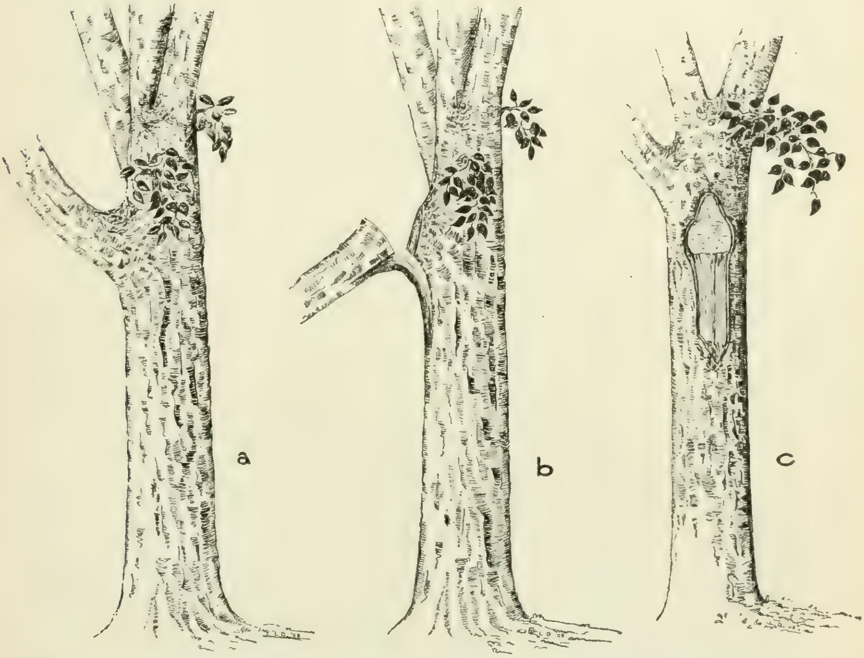

Fig. 24. — Too common method of pruning limbs, resulting in the disfiguration of the tree: (*a*) tree before pruning; (*b*) limb cut too close, resulting in the peeling of the bark; (*c*) unsightly wound caused by this method of pruning.

The cutting back of old trees is usually disappointing. It is often a question as to whether this is worth while, although if not too far gone, old trees may be restored to a more or less vigorous condition by judicious pruning, tillage and feeding. When elm branches a foot or more in diameter are topped, nothing but a bushy growth results. By removing all but a single sprout, thus diverting the plastic materials, much better growth may be obtained, and replacing of the sacrificed member may be more readily obtained.

There is a difference of opinion as to the best time to prune, some authorities advocating spring and others preferring the fall of the year. Many people prune when the tree is in foliage, — in May or later. There are advantages in pruning in either season. Since trees occasionally bleed when pruned in early summer, painting the wounds is not always successfully accomplished under these conditions; on the other hand, scars on vigorous trees are likely to heal somewhat during the summer if the pruning is done early.

The tools required in pruning are as follows: for general work, a good coarse-tooth, wide-set saw (5 teeth per inch); for larger limbs, a small 3 or 4 foot hand cross-cut saw; and for smaller limbs not easily accessible, a pole saw is convenient. Pole-saw blades may be ordered through hardware dealers, and may be fitted to poles of any desired length. A pole hook, which can be made by any blacksmith, is often useful for removing the small dead branches. For lowering large limbs a set of blocks is necessary, and in the felling of trees a cross-cut saw is indispensable. Ropes of various sizes, iron wedges for felling trees, axes, mallets and chisels, ladders, spurs for climbing, etc., are also indispensable.

The above are the most essential tools for pruning shade trees, although there are others which are extremely useful and time saving.

Healing of Wounds.

A protective feature characteristic of all plants is well illustrated in the healing of wounds. The healing tissues (callus) in a tree are the cambium and adjacent meristematic cells located between the wood and the outer bark. The plastic substances which provide the material for growth and healing are manufactured in the leaf, and are transferred through certain tissues of the inner bark (phloem) adjacent to the cambium to various parts of the tree. When the tree is girdled or the bark removed no growth takes place below the girdling because the channels of transportation are destroyed.

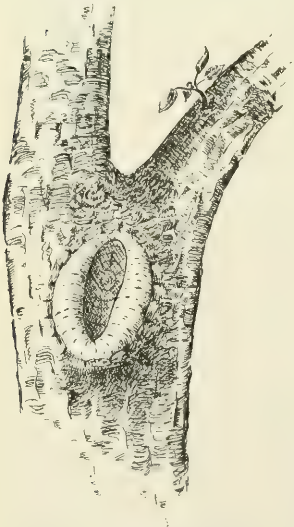

FIG. 25. — Healing of wound. Most active healing follows most direct lines of transference of plastic materials.

In some young plants the pith cells possess the power to form a callus, but such cases are rare and of little importance. The younger the tissue or organ the more quickly it will heal, providing other things are favorable, and vigorous trees will form a callus much more quickly than old or weak ones. Since the plastic substances are manufactured in the leaf, and since it is these substances which are necessary for the development of healing tissue, it is only when wounds are located along the line of transference of the plastic substance that they develop healing tissue. The sides of a circular wound as a rule heal over most rapidly because they are most directly in the channels of the transference of the plastic substances, and the top and bottom of the wound heal more slowly. When these facts are borne in mind it will be seen that a proper shaping of the wound is important for the development of a more or less even callus formation. (See Fig. 25.) Cuts made near large, leafy branches are more likely to heal quickly than those near small ones, for the reason that a larger amount of the plastic materials is available.

To facilitate healing, recourse is occasionally made to cutting the bark smooth around the stumps of the removed limbs, and it is also claimed that after the callus is well started a recutting of the surface stimulates its growth.

Moisture is said to stimulate the growth of the callus, and the old practice of covering the wound with a mixture of cow manure, clay and lime had this object in view.

Disinfectants for Wounds and Cavities.

There are many erroneous ideas concerning the effectiveness of disinfectants and their use in general. This is particularly true of disinfecting materials used in tree work. Because a certain disinfectant is used successfully for one purpose it does not follow that it is applicable to all. As a matter of fact, all disinfectants are limited in their usefulness owing to the great variation existing in organisms as regards amenability to treatment by chemical substances. Disinfectants, therefore, possess specific rather than general properties, which are determined by many different factors. Copper sulfate, for example, is remarkably effective

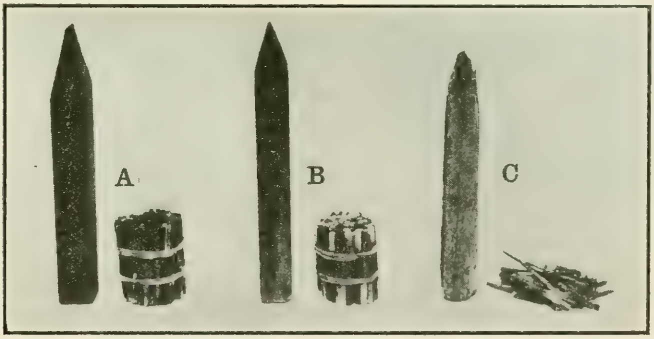

FIG. 26. — Effects of antiseptic treatment of wood in soil two years: (*a*) treated with Carbolineum; (*b*) creosote; (*c*) untreated. Little difference between (*a*) and (*b*); in (*c*) practically all decayed and about 50 per cent. completely.

when applied to reservoirs, ponds, etc., for cleaning out objectionable growths of many kinds, even when used at 1 to 1,000,000 parts or at 1 to 10,000,000 parts; while to be effective against the common blue mold, *Penicillium*, which is often found in the wood of dead trees, it requires a solution of about 1 to 30, or several thousand times stronger.

In the disinfection of wood tissues the following points should be considered. The disinfectant should be capable of penetrating wood tissues. An oily substance, which has more penetrating power, is far better adapted to this purpose than a watery solution. The substance should be only slightly volatile and should keep its original form, or at any rate its antiseptic properties, indefinitely. Copper sulfate, corrosive sublimate, formalin, lime and sulfur, and Bordeaux mixture have been used as disinfectants and preservatives in the treatment of tree cavities, scars and wounds, and while all of the above-named substances have specific disinfecting properties it does not necessarily follow that they are adapted to wood tissues.

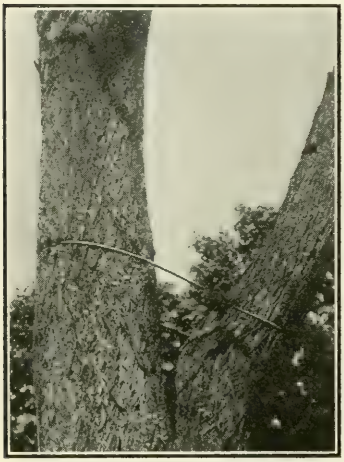

Fig. 27. — Inferior mechanical work. Iron band too low for best support, and also causing girdling.

The above-named substances possess limited powers of penetration, and have little or no permanent antiseptic value when applied to tree wounds. Coal tar is also objectionable because of its lack of penetrating power, and because it loses its fungicidal value as it becomes hard. A thick, nonpenetrating material applied to wood is not only of no value, but becomes an injurious agent, as shown by the treatment of shingles on roofs. The old practice of tarring roofs simply induced decay because the tar coating conserved moisture in the shingles, and decay followed more rapidly than in the untreated shingles. Coal tar, however, is useful in covering surfaces previously treated antiseptically. In fact, the use of creosote followed by coal tar constitutes one of the best scientific treatments known, especially for exposed wounds. On the other hand, paint which contains plenty of oil is valuable, as has been proved by long years of experience. It lacks durability however.

Shellac dissolved in alcohol and applied to wounds is serviceable for filling the pores of wood and preventing decay, and hence is of some value as a wound dressing. Gas tar and liquid asphaltum are also sometimes used to cover wounds, and there are specially prepared paints and other substances for use as wound dressings. Even common painter's oil is excellent for the treatment of wounds, as it prevents checking of the wood tissue. As the transpiration current remains practically normal because checking of the wood is prevented, trees will support a large amount of foliage even when badly girdled. Painter's oil is especially suitable for bark wounds. These should be first properly shaped and their surfaces scraped before applying the oil or other substances. Practically all disinfectants injure delicate tissue such as the cambium layer, but it should be borne in mind that the cambium always dies back to a certain extent when exposed to the air, and more of this dying back results from dessication than from the use of antiseptics. All antiseptics must be used with judgment, especially when the vital tissues are likely to be seriously injured by their use.

Chaining and Bolting Trees.

It often becomes necessary to bolt or chain trees to render them more secure and to prevent injury and disfiguration. As this process is not necessarily always an expensive one it should be much more commonly employed, many valuable trees having been made practically worthless by the loss of large limbs during wind storms, etc. Although the elm is a very tenacious tree with wood that is very difficult to work up into fuel, it is very likely to split. For this reason it is advisable to chain and bolt elms and any other trees which show a tendency to weakness. For an outlay of from $10 to $15 it is often possible to save a tree worth $150 to $200 from destruction.

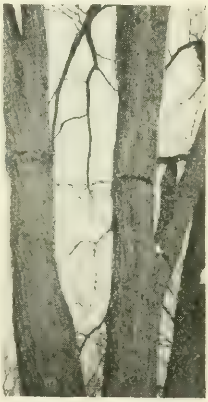

FIG. 28. — Girdling by chain placed around tree.

Different devices are employed for strengthening trees. Some of these are objectionable and do more harm than good. It has been a common practice to place chains around limbs to prevent their splitting, but as the tree develops the chains become imbedded in the bark, resulting in partial girdling, and ultimately disfiguring and injuring the tree.

Another equally objectionable method which invariably results in girdling consists in placing strong bands of iron around limbs and trunks. For making trees more secure some prefer to use an iron rod rather than a chain, and although both have their place, in our estimation the chain system is the better for most purposes. If it is necessary to fasten branches near the point of forking where swaying is limited an iron rod is preferable; but for connecting limbs a few feet apart more or less remote from their junction with one another (where swaying is more pronounced) the chain method is superior. A rod is likely to break when the tree is swayed by the wind owing to its rigidity, whereas a chain, which is flexible, will stand the strain better. Moreover, a chain is easier to place than a solid rod, as less attention has to be given to boring the holes. However, if one or two links are placed in the rod, as is sometimes done, this difficulty is of course obviated to some extent.

. Galvanized stranded guy wire or cables, such as are employed by public-service corporations for anchoring their poles, are superior to either chains or rods for holding in place defective limbs and branches, and are far more pleasing to the eye. These wire cables may be obtained in various sizes and are much cheaper and stronger than chains. Their tensile strength varies according to size and quality from a few thousand to several thousand pounds, but the more flexible cables are best suited to this work. A chain is as strong as its weakest link or member, which sometimes may be very weak, whereas a stranded wire cable is much more homogeneous in its construction and less likely to break. The strain which it is necessary to overcome in swaying trees is often very great, and we have known many chains to break when the links were composed of three-eighths or five-eighths inch iron. Wire cables and chains are usually used with eyebolts, provided with washer and nuts, but the eyebolt often constitutes the weakest feature. It is therefore important that only the best quality of iron be used in the construction of eyebolts. Moreover, work of this nature demands skillful blacksmithing.

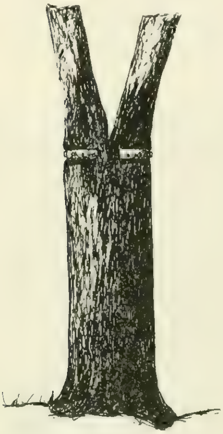

FIG. 29. — Showing combination of bolting and banding method which caused girdling to the tree.

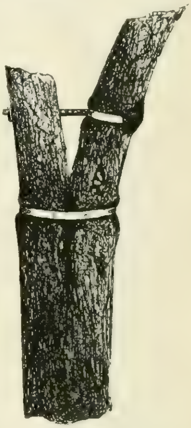

FIG. 30. — Illustrating the combination banding and bolting method. It is extremely faulty in all respects.

When stranded cables are used the eyebolt method is sometimes dispensed with. In this case the wire passes through a hole in the tree and around an embedded piece of iron. The wire method is also valuable in temporarily rendering safe weak or dangerous limbs, and in anchoring more or less decrepit trees to strong supports.

Most of the chaining, bolting, etc., observed in trees follows extremely poor mechanical principles. The chains or bolts are often too small, and are seldom placed advantageously as regards leverage, the majority being placed too low or too near the crotch of the tree, thus requiring too much strain to be overcome. Where large limbs are involved, most eyebolts should be 1 inch in diameter and extend through the tree, these being supplied with a 3 or 4 inch washer and nut. The practice of screwing eyebolts or hooks into a tree for a short distance for the purpose of attaching a chain is bad, since they may be pulled out or broken off with the slightest strain, and only a bolt passing through the tree, provided with a washer and nut, is suitable for such work. If stranded wire is employed it may pass around an imbedded iron bolt at the back side of the limbs.

In any system of strengthening trees, whether by wires or other methods, the best mechanical principles should be employed and a careful estimate made of the amount of load that must be carried; also the proper angle of attachment, etc. The amount of strain to overcome in wiring trees is invariably underestimated, even with an ordinary amount of swaying. During severe tempests hardly any tree is safe, a twisting air movement of great velocity acting as a severe strain. It is always wise to have the chain or wire used far within the limit of safety. Since the limbs or branches of a tree have a tendency to move inwards during cold weather, causing chains and wires to become slack, all wires should be drawn tight at their installation.

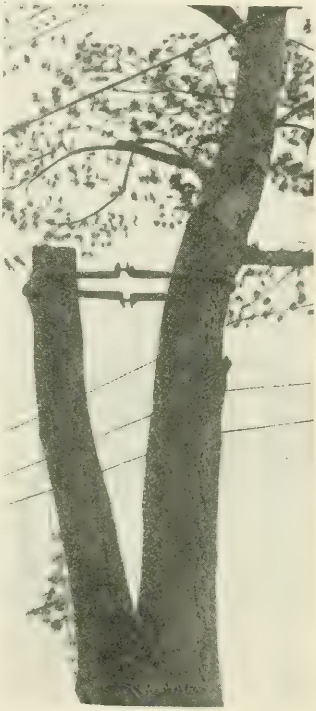

FIG. 31. — Iron band around limbs of tree. An objectionable method.

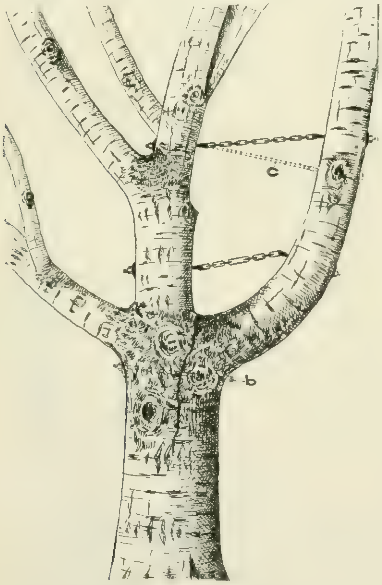

FIG. 32. — Improper method of chaining tree. Dotted lines show more effective method: (*b*) bolt, (*c*) chain. All chains, however, too low.

In many cases of chaining and bolting the washer and nut are placed on the outside of the bark, and often no attempt is made to cut off the ends of the bolts. The unsightliness of this method makes it objectionable. It is better to cover the nut and washer, which may be done by countersinking them into the wood of the tree by means of a gauge or extension bit, and the free ends of the bolts should be cut off close to the nuts. The washer and nut should be well imbedded in thick paint or coal tar, and either elastic or Portland cement used to cover them, allowing the cement to come flush with the exterior surface of the wood. By this method the ends of the bolt, washer and nut are covered, and the scar produced by this operation will heal over in a short time, leaving no trace.[1]

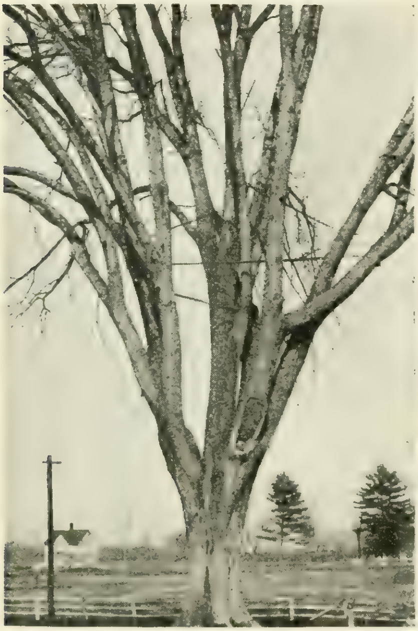

FIG. 33. — Chain and bolt method of supporting limbs.

The poles of public service corporations are often attached to trees by guy wires, and care should be taken to prevent injury to the tree from girdling, etc. A large wire loop placed round a tree and properly insulated from the trunk by special hard wood blocks is usually harmless, and is more desirable on streets than other often unsightly methods of anchoring poles. These blocks may be made from oak, and should be 2 inches wide, 1½ inches thick and 8 or 10 inches long for heavy wires. They should be provided with a shallow groove to take the wire, the groove being made a trifle narrower than the wire to insure a tight fit. (See Fig. 42.)

Treating Decayed Cavities, Fillings, etc.

Decayed cavities in trees are very undesirable since any fungi and insects which may be present will extend their range of activity, causing decay and shortening the life of the tree. Cavities result from poor pruning of limbs, the breaking off of branches,

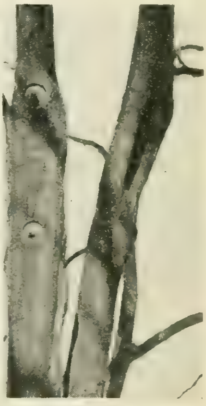

FIG. 34. — Tree properly bolted; washer countersunk and imbedded in cement.

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[1] The weight of a limb may be roughly obtained by multiplying the average diameter by the length. This calculation should include the numerous small branches, limbs, etc.

According to Prof. C. S. Sargent (Woods of the United States, 1885), the weight of a cubic foot of elm wood is 40.55 pounds when dried at 100° C., and according to W. S. Clark (32d Rept. Mass. State Board of Agriculture for 1874) the amount of water in elm wood varies from 40 to 60 per cent.; thus a cubic foot of green elm wood would equal about 60 pounds. A limb 40 feet long with an average diameter of 8 inches would weigh about 840 pounds, and a section about 34 inches long would equal 1 cubic foot. Of course the leverage which must be overcome is determined by angles of the limb and point of attachment of the chain or wire. (See Fig. 36.)

and other injuries which are not followed by proper treatment at the time.

The treatment of cavities naturally involves some expense, but if a tree is of any value it is worth treating, even though its value may be sentimental in nature. There are many trees which to the casual observer would appear to be of little consequence, but the associations connected with them may be highly cherished. Then, again, the location is often important. A tree may furnish shade which cannot be dispensed with, and even if old and decayed it is often more satisfactory to treat it than to wait for a new tree to grow.

The rationale underlying the cleaning and filling of cavities is similar to that in dentistry. If the work is properly done, and if antiseptic conditions are secured, the length of a tree's life may be extended.

For centuries trees have been treated in various ways. Cavities have been filled with wood, brick, stone, cement and other substances, but as a rule much of this earlier work was very crude in nature, and has accomplished little or nothing toward the prevention of decay. During the past few years, however, more scientific attention has been given to the treatment of decayed cavities in trees, and many good examples may be seen here and there, although it must be confessed that as yet the work is in more or less of an experimental stage.[1]

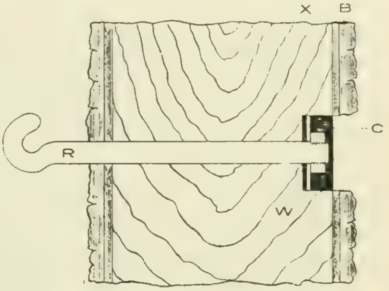

FIG. 35.—Longitudinal section of limb, showing method of bolting. B, bark; X, wood; R, bolt; W, washer; C, cement.

As has been said, the object of treating decayed cavities is to prevent further decay and to prolong the life of the tree; but there is no particular reason why people should spend one or two thousand dollars on a single tree for repair work when it is possible and certainly more reasonable to transplant a larger and better one for two or three hundred dollars.

The first step in the treatment of cavities is to remove all decayed and infected tissue, which is done by a thorough cleaning out of the cavity.

Second, to treat antiseptically all the exposed tissues which are susceptible to decay, preventing further disintegration. The disinfecting substance should be one which can safely be used and still be permanently effective. Creosote is one of the best antiseptics because it possesses superior properties for penetrating wood, and is quite permanent as a disinfectant. In some cavity work this is as far as it is necessary to proceed, especially in the treatment of old, weak, decrepit trees which at most have only a brief period to live, and when there is already considerable strengthening tissue owing to the inward growth of the callus and wood. It is often inadvisable to remove this strengthening tissue and fill the cavity. (See Fig. 43.)

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[1] The writer's first attempt to establish a course covering shade-tree management was in 1895 although the research work concerning shade-tree problems antedated this period. At that time there was little material of a reliable nature at hand touching upon the many shade-tree problems which were continually coming up, and it was practically impossible to organize a course of study relative to the subject which would be of any great practical, scientific or pedagogical value. It was, therefore, apparent from the first that an extensive course of study covering this subject, to be of practical value, would require a scientific basis. However, the numerous investigations carried on during recent years relating to shade-tree problems have placed this subject on an entirely different basis, although there is still great opportunity for further research work along these lines.

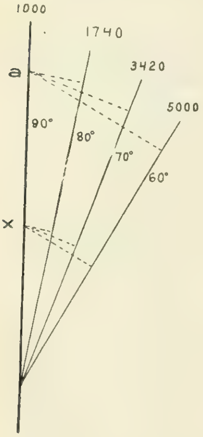

FIG. 36. — Showing relative strain in pounds on wire or chain holding limbs at different angles. The strain at *x* would be twice as much as at *a*.

Third, to cover the orifice or opening of the cavity to direct the growth of the callus or healing tissue. However, trees are seldom if ever strengthened by fillings; on the other hand, they are too often weakened by overloading, although ultimately, as new tissue develops over the surface of the filling, strengthening may follow as a result of growth.

Innumerable instances may be observed of positively injurious tree repair work which has been done by incompetent men, some of whom are downright scoundrels; and many trees have come to a sad end from overloading with heavy concrete. Sometimes the tree collapses before the contractor actually finishes the work, in which case litigation usually follows.

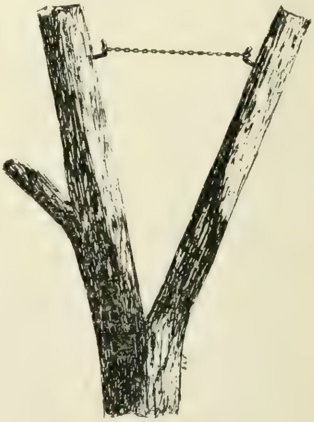

FIG. 37. — Illustrating a faulty method of chaining trees.

The writer has had many opportunities to observe cavity work in trees. Some of these cavities were treated forty years ago, and when thorough cleaning and antiseptic treatment were given the cavities, decay has been arrested to a very remarkable extent. Even some of the work done by ignorant men and amateurs, who are unable to distinguish between normal and infected wood, has been effective in arresting decay, although only the punk and discolored tissue is usually removed from the cavities.

While some progress has been made in cavity treatment during recent years, the greatest drawback to the development of a more scientific and intelligent method of treatment is ignorance and incompetency on the part of those undertaking such work. The use of worthless disinfectants, the improper shaping of the cavity opening, and many other wrong methods show a total disregard for the first principles of scientific treatment and for common sense. It is unfortunate that so many have undertaken to do tree repair work without adequate training or special aptitude for it. There are innumerable so-called "tree experts," "tree specialists," etc., whose whole experience consists in having filled one or two tree cavities. They possess little or no knowledge of trees or tree problems. Too much stress is also laid on the external appearance and smoothness of their cavity work. They seemingly fail to realize that the scientific treatment of a wound or cavity is fully as important as its appearance when done.

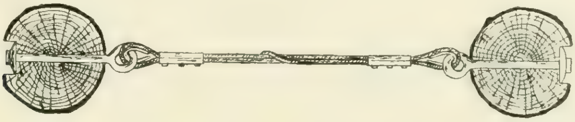

FIG. 38. — **Showing cross-section illustrating the eyebolt and the stranded wire method of attachment. (Compare Fig. 39.)**

The principal advance in cavity work has consisted in more thorough cleaning and more effective antiseptic treatment, and some improvement has been made in the technique of cement work. However, these innovations are of minor importance, considering the extent of the work done and the opportunities offered for improvement in the scientific and rational treatment of cavities.

Methods of treating Cavities. — The greatest need in tree cavity work at the present time is more suitable material and improvement in methods of doing the work. There is no reason why a cavity should be filled, — in fact, there are reasons why it should not. The principal problems associated with cavity work are those involving the eliminating of fillings of all descriptions. A durable material with physical properties similar to those of the tree to direct the callus growth must also be found.

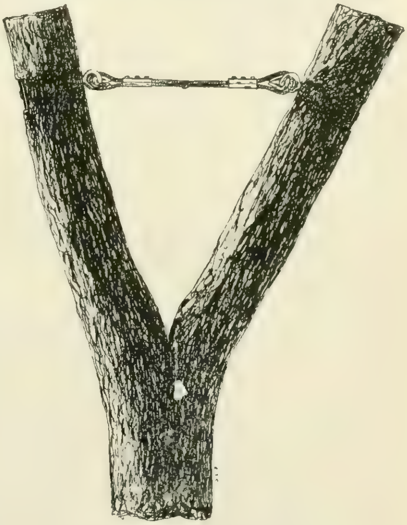

FIG. 39. — **Illustrating eyebolt and stranded wire method of attachment.**

There are several methods for the treatment of cavities, some of which were first used years ago. Brick and stone laid in cement have been used as a filling to cover the cavity opening, and some years ago use was made of irregular pieces of untreated wood for filling cavities. However, cement in different forms has been most frequently employed for cavity fillings, and various metals have been used as a covering for the cavity opening, Use has also been made of wire mesh covered with elastic cement; combinations of asphalt and sawdust; paraffine and sawdust; wood pulp and cement; excelsior and asphalt; sawdust, tar and oakum; certain composite substances like papier-maché; special floor cements; and chemically treated wooden blocks.

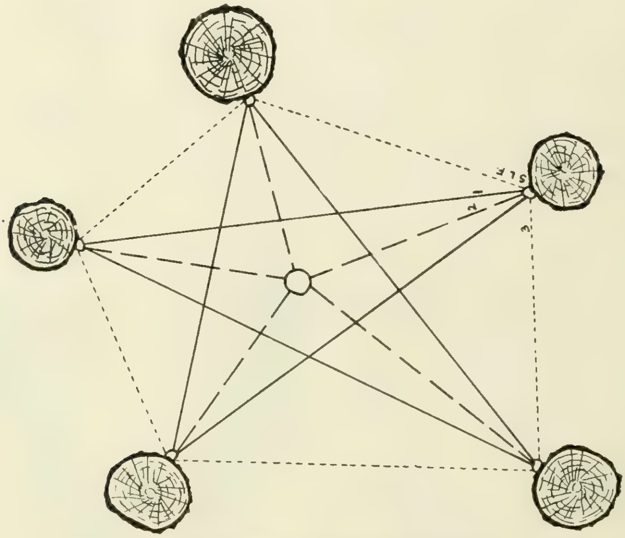

FIG. 40.—Different methods of fastening branches. The solid lines represent the best method; dotted lines inferior methods.

Various disinfectants, such as copper sulfate, corrosive sublimate, Bordeaux mixture, kerosene, formalin, carbolineum, coal tar, creosote, etc., have been employed for cavity work, but some of them are poorly adapted for the purpose. Creosote and carbolineum are similar in nature, and are the best materials for disinfecting cavities. The former apparently possesses greater power of penetration than the latter, although carbolineum seems to form a more permanent external covering than creosote. (See Fig. 26.) Owing to the slow penetration of all disinfectants into moist wood, more than one treatment is needed, and if the cavity is left open for a while before receiving later treatments, so much the better.

Although there have been complaints that creosote injures trees, we have never observed any such injury, notwithstanding the fact that we have treated cavities within 1 inch of the vital area. In all instances observed, where injury was reported from the use of this substance, the pathological conditions were due to other causes, and were present previous to the time of the repair work.

The expense involved in the different methods of treating cavities varies considerably, and it is not well to increase it unnecessarily. However, if a tree is worth treating the work should be done well, and the more costly methods need not be condemned if they achieve superior results. Before an attempt is made to repair a tree a thorough examination should be made, but this is seldom done. Often a considerable portion of a tree above and below the ground may be dead without the fact being noticeable to the casual observer. A careful examination would reveal the fact that the tree is not worth expensive treatment.

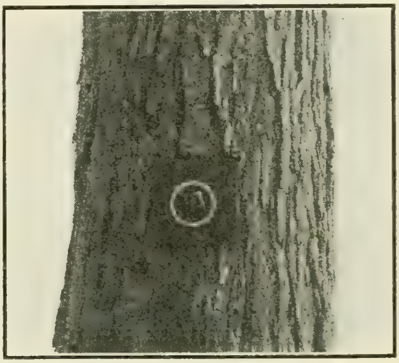

FIG. 41. — Bolt passing through a tree with large square washer. A smaller round one, represented by the white circle, is a more desirable form to use.

Shaping the Cavity.—The shape of the cavity interior is determined largely by the necessary removal of the decayed material. As the decay of the heartwood is usually more extensive than that of the sapwood, the interior dimensions of a cavity are usually greater than those of the orifice or opening. A shoulder is thus formed, and this is of great advantage when cement and other substances are used in filling. In cases where there is no shoulder, spikes may be driven into the wood or iron bolts used, or grooves in the wood may be chiseled out to anchor the filling substance more thoroughly and to prevent its dislocation. But the shaping of the cavity opening or orifice is most important, the main object in filling a cavity or covering its opening being to direct the callus

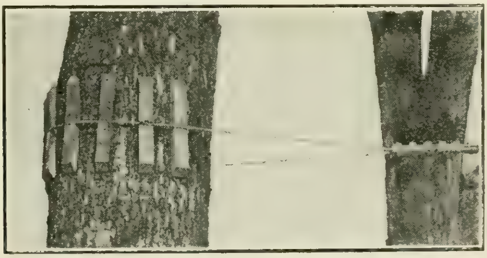

FIG. 42. — Least objectionable method of anchoring guy wires to trees.

or healing tissue. It is therefore essential that the shape of the cavity opening conform to the path of the translocated plastic substances of the tree. These are confined to the phloëm, or inner bark. The sides of the cavity opening should, in a general way, conform; and the less the irregularity of the edges of the opening the better.

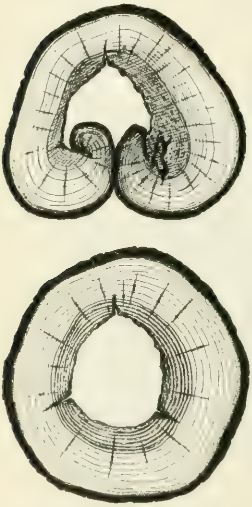

FIG. 43. — Demonstrating the object of treating cavities. Upper figure shows cavity of long standing, with callus curved in, which, if it had been treated, would be as represented below.

If the cavity is above the surface of the ground the apex and base of the opening should never be truncated or flattened, but should be apiculate or pointed. There is no particular objection, however, to having the opening of the cavity perfectly square or rectangular if the bark is removed above and below the opening and brought to a pointed or rounded termination. (See Fig. 49.) This allows the healing tissue to form regularly and uniformly over the outside of the cavity. This also holds true in the treatment of scars and abrasions on trees. After removing the bark the wood should be scraped and treated as with any wound.

Concrete Fillings. — Concrete has been used more largely than any other substance for filling cavities in trees, but its physical properties are so unlike those of wood that it has never been regarded by competent authorities as a suitable material for work of this nature. By some workers its use has only been tolerated until something better could be substituted.

Some of the numerous objections to be raised against filling cavities with cement are as follows: —

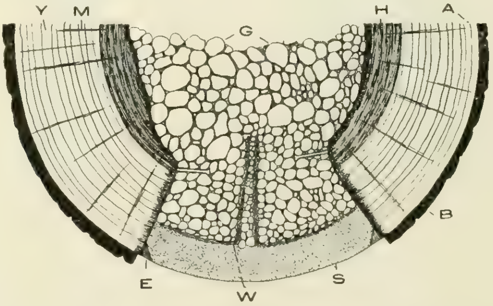

FIG. 44. — Cross-section of filled cavity showing one method of treatment. B, bark; Y, sapwood; M, medullary rays; H, heartwood; A, annual rings, G, grouting; S, cement surface covering; W, wire re-enforcement; E, elastic cement. Inferior to the dry cement methods now used.

(*a*) Cement cannot accommodate itself to the constant swaying movements of trees. As a consequence the fillings are likely to become displaced and crack, although this is not so often the case with fillings low in the tree. This unavoidable cracking of the cement renders it extremely unsuitable for use in cavities.

(*b*) Cement upon drying shrinks from the wood, furnishing an entrance for water, frost and injurious organisms which may cause damage if the conditions are favorable.

(*c*) It is practically impossible to stop bleeding from a cavity that has been filled with cement. This exudating sap or "slimeflux," which is not uncommon in trees, discolors the bark and in some cases injures the underlying tissue.

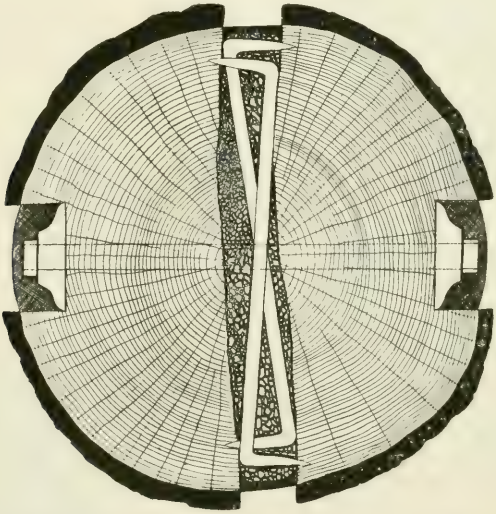

FIG. 45.—Cross-section of split tree with bolt and countersunk nuts and washers and iron braces to obviate movement. Instead of cement, wooden blocks should be employed to cover the opening of the cavity.

(*d*) There is nothing to be gained from filling a tree cavity with cement or any material. The chief object of filling is to protect the healing tissue or callus of the tree after the cavity has been thoroughly cleaned and disinfected, and this can be accomplished by other methods.

(*e*) Cement does not in any case strengthen the tree; on the contrary, it often proves weakening because of its cumbersome and quite unnecessary weight. It is not adapted to horizontal cavities, which are difficult to seal sufficiently to prevent trouble from water, etc.

(*f*) The several schemes devised to increase the efficiency of cement fillings, such as re-enforcing with iron, wire, etc., covering the cement surface with metal, the use of elastic material and special grooves, laying the cement in sections, and many others, have not proved of any material value in solving the problem.

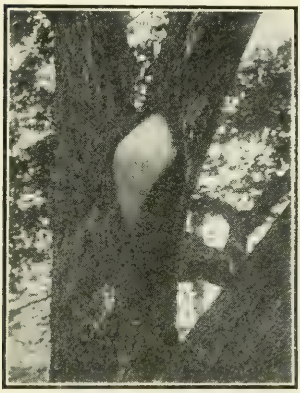

FIG. 46. — Cement-filled cavity favorably shaped for healing over.

(*g*) The tissues back of a cavity are rendered more susceptible to decay by the cement filling. This is especially true if proper antiseptic treatment is not given, or if the cavity is not thoroughly cleaned.

From the various objections given it follows that it is often better to leave the cavity open, or merely to cover the same, than to fill with cement.

Several methods have been employed for the use of cement, and a detailed description of all of them is hardly worth while. It has been extensively employed as a filling, and also as a covering for the cavity opening, in which case the main cavity itself would be left unfilled. In most of the older work in filling cavities with cement the opening of the cavity was boarded up and grouting of a more or less soft consistency, consisting of 1 part cement to 5 or 8 of sand, gravel or other material, was poured in. When this was partially set the boards were removed and the surface of the grouting was coated with about 1 part cement to 2 parts sand, this extending to the outer edges of the wood and conforming to the general contour of the tree. In other cases cement in the proportion of 1 part to 2 or 3 parts of sand has been used in a relatively dry form, applied in small quantities, and thoroughly tamped. This method does not require the use of boards at the cavity opening, as the cement, which is uniform throughout, is gradually built up until the filling process is completed. The outer surface conforms to the general contour of the tree. The use of relatively dry cement has proved more desirable for cavity work than grouting, followed by a surface covering of a different consistency, and has done away with considerable of the cracking and dislodgment of cement which followed surface covering over grouting. In cavity work of all kinds where cement is used, nails, spikes, wires, iron rods and bolts, wire mesh,

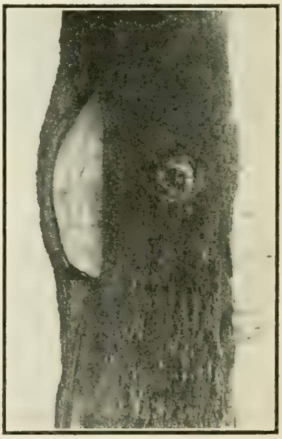

FIG. 47.—Cement-filled cavity with bolt.

etc., have been used freely in numerous ways for re-enforcing. When the cavity has no "shoulders" to hold the cement in place, spikes driven into the wood are effective in anchoring the cement, and we have observed such fillings to remain undisturbed for many years.

Any filling substance or covering of a cavity should always come flush with the exterior of the wood. For this purpose it is best to cut the bark back as little as possible to expose the edge of the wood to view. Special grooves cut in the wood of the cavity just anterior to the outer edge of the wood have been used with the idea of directing the flow of surface water which may enter the cavity, or that arising from the interior caused by bleeding, but these grooves have not proved of practical value. A V-shaped groove cut in the edges of the cement before hardening, filled with elastic cement to prevent water from entering, is sometimes used. As there is always more or less separation of the cement from the wood after setting or hardening use has been made of thick elastic substances to cover the surface of the cavity to make the contact more complete.

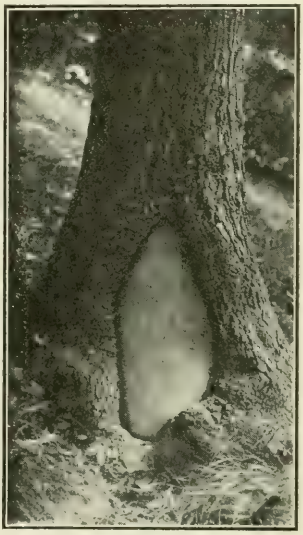

FIG. 48. — Stump growth of white oak with cavity cleaned and treated with creosote and filled with cement. Edge of cavity effectively sealed with elastic cement.

Sectional Concrete Fillings. — The writer first experimented with sectional concrete fillings in 1902 and 1903, and has at different times since suggested this method of filling cavities to those seeking to avoid cracking of the cement where considerable movement exists. In our original experiments the cement was laid in sections, each section being allowed to become set or hardened before another was put on. The sections were further separated from one another by the use of such substances as cardboard or tarred paper, fiberoid, elastic cement or wire mesh. Our idea in developing the use of sectional work was to eliminate cracking of the cement which so commonly follows the use of this substance, and the purpose of using more or less elastic substances between the sections was to form a bed for each section or independent unit to move upon during swaying without causing chipping of the edges of the sectional blocks. The sectional method of filling has been employed quite extensively within the last six years, and at present it constitutes the best method of employing concrete cement in tree cavities.

In some of this work the sections are bolted to the tree, thus restricting independent movement to a certain extent by anchoring the sections. In consequence of this anchoring the sections load the tree with weight, whereas in basal cavities if not anchored they would not, and with the use of entirely independent sections the movements of cement would be slightly different.

The first to use sectional concrete in tree cavities with bolted sections was probably the late city forester W. F. Gale of Springfield, about 1906. Mr. Gale employed two cross bolts to each section, the sections being about 20 inches long and separated in part by wire mesh. After the cement had sufficiently hardened the bolts were tightened to separate the sections or individual units still further. At the present time tarred paper is usually employed between sections, but where there is much movement this substance is hardly thick enough, especially on the outer edges, to prevent chipping. We had this feature in mind in our original sectional work. With the judicious use of iron bolts (which should in our opinion be independent of the sections) in order to secure rigidity, the sectional cement method has proved superior to the older methods of filling cavities, since it has done away with much miscellaneous cracking and dislodgment of fillings.

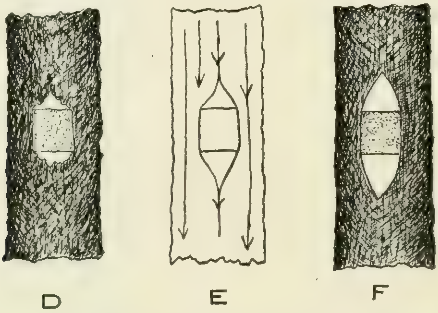

FIG. 49.—Showing a square cavity filled with cement. D, disintegrated bark above and below the filling; E, general path of plastic or healing substances; F, bark cut to point to accommodate the process of healing and conforming with the path of healing substances.

Much improvement in the quality of the cement work done on trees has been made within the last few years, especially in cement technique, and some of the Portland cement surface in cavities is excellent. A great deal of puttering and detail work such as thorough tamping and troweling of the cement is often done in tree cavity work, especially when the contract is for work by the hour. Thorough tamping and troweling improve the cement, and as a result of this frequent time-killing process practiced by certain unscrupulous workers some of the best individual examples of cement technique may be found in trees. While the sectional method of filling cavities with cement has caused some advance in cavity cement work, it does not solve the problem of treating cavities. In many cases of sectional work it is an absolute failure. This is true especially when there is too much swaying or when the tree cannot stand the load, or when there is too much crushing force, as in narrow cavities. All concrete work on trees is better adapted to cavities located near the ground or below the surface than to high cavities where swaying constitutes an important factor, and where an increase in the load which a tree is obliged to carry is objectionable.

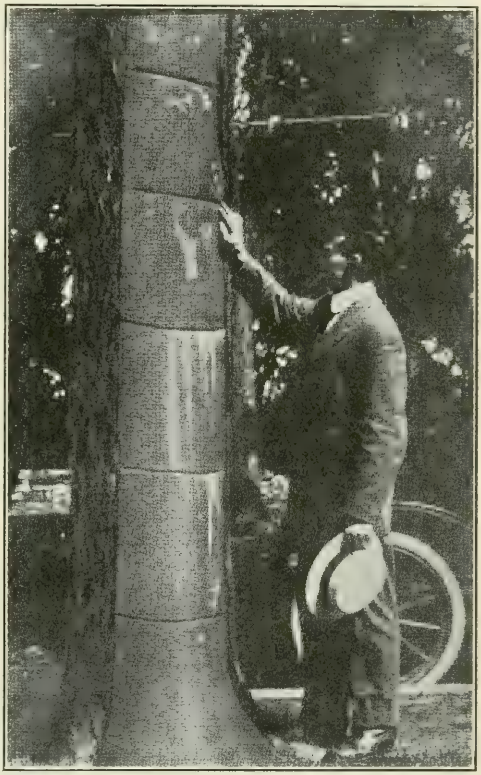

FIG. 50. — Concrete filling built in sections. (From "Tree Talk.")

Concrete Coverings for the Cavity Opening. — Concrete may be used to advantage as a covering for cavity openings to form a surface for directing the healing tissue. With this method the interior of the cavity is left unfilled, and if the cement is properly reenforced with iron the scheme is practicable and possesses many advantages. The writer has treated some large cavities by this method, and it has proved as satisfactory as solid fillings. Considerable cement is also saved. (See Figs. 51 and 52.)

Metal Coverings. — Metal was much used formerly, and is to some extent to-day, to cover the openings of cavities, and some very creditable work has been done in this line. For this purpose tin or zinc is cut and shaped to meet the requirements of the cavity opening, and after some of the bark has been cut away the metal is securely fastened to the sap wood with tacks. With this method of treating cavities the usual cleaning and disinfecting are done, but the cavity itself is left unfilled.

The principle underlying this method is good, but metal has not proved a durable covering, nor are its physical properties suitable to work of this nature. It is affected too greatly by changes in temperature, which has a tendency to displace the tacks; consequently the metal covering becomes loose and valueless in a short time. Metal is inclined to deteriorate in a few years, and cannot accommodate itself to much movement in the tree unless it is used in sections and imbricated or overlapped like shingles.

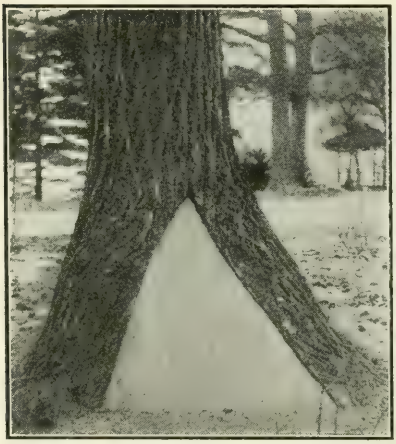

FIG. 51. — Chestnut tree cavity resulting from stump growth, with cavity covering of cement about 6 inches thick. (See Fig. 52.)

Sometimes metal is used to cover cement-filled cavities, but this is of no particular value, and does not improve the appearance of the tree. The principal purpose in using it over cement is to cover the cracks, and when used in connection with iron bands over the surface it is supposed to help hold the cement in place. In some cases where metal is used in this way it is lapped over on the bark 4 or 5 inches, but this destroys the underlying tissues and arrests their future development, thus defeating one of the main objects of treating cavities, — *i.e.*, encouraging and directing the healing tissue or callus formation.

Elastic Cement. — Elastic cement, such as is employed by slaters, has been used for some years in tree repair work, and was recommended for this purpose by the Massachusetts Forestry Association about 1900. Its principal value in tree repair work consists in its elastic properties and its adaptability to places where there is considerable movement. It is too expensive for use in large cavities, costing from 4 to 15 cents per pound, but it has been employed to some extent for filling small spaces and also as a thin covering for cavity openings. In the latter case wire mesh is strung across the cavity opening, the wire mesh being re-enforced with iron and shaped to conform to the outer contour of the tree; and the elastic cement is plastered on the mesh. (See Figs. 54 and 55.)

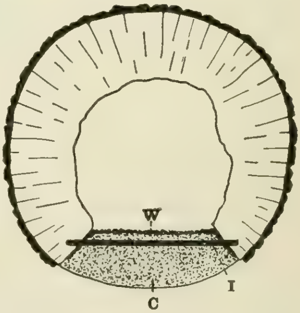

FIG. 52. — Illustrating cross-section of the cement surface covering to cavity shown in Fig. 51. W, wire stapled to sides of cavity; I, iron re-enforcing; C, cement.

This method of treating cavities has been especially recommended by Mr. L. F. Prouty, associated with the city forestry department, Springfield, Mass., who has made quite a little use of elastic cement for cavity work. One of the drawbacks in the use of this substance for tree work is that it does not harden sufficiently, the surface easily becoming disfigured. On the other hand, it is valuable for cavities in high swaying trunks and limbs of trees, and especially for cavities with horizontal openings.

Wood pulp with a thin facing of Portland cement has also been employed for covering the openings of cavities.

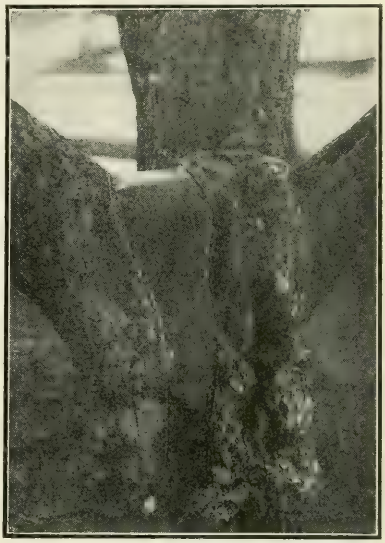

FIG. 53. — Cavity in apple tree cleaned out, treated antiseptically, and surface covered with tin.

Asphalt Fillings. — During the last twenty years numerous attempts have been made to use asphalt in tree repair work, and more recently it has been employed in combination with other substances. Asphalt and sawdust have been used for cavity work by Mr. John Boddy,[1] city forester of Cleveland, Ohio. For cavities in swaying branches he uses 1 part asphalt to 3 or 4 parts sawdust, and for other cavities 1 part asphalt to 5 or 6 parts sawdust. The sawdust is stirred into the hot asphaltum until the desired consistency is obtained, and the mixture while still hot is put into the cavities with tools smeared with crude oil. Mr. Boddy recommends a grade of asphaltum termed "Byerlyte" as best suited for this purpose. This is derived from refining petroleum with an asphaltum basis, and is the same as that used on street pavements. The mixture of asphaltum and sawdust is better adapted physically to the movements of the trees than the more rigid Portland cement.

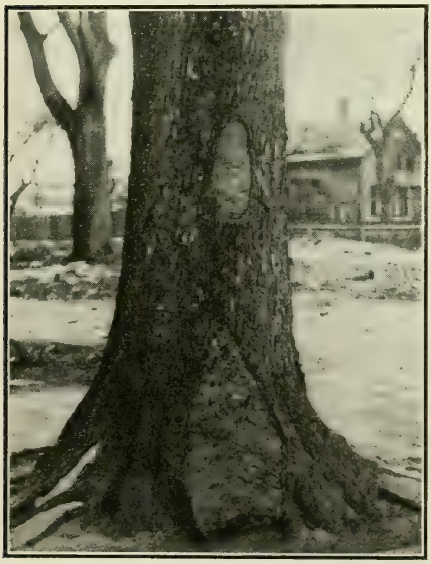

FIG. 54. — Elastic cement covering of cavity opening. Wire mesh only supports the thin covering of cement. (After L. F. Prouty.)

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[1] Ohio Agr. Exp. Sta. Cir. No. 150, June 11, 1915.

Another method of treating tree cavities with the use of asphalt has been devised and described by Elbert Peets. This consists of using brickets or units composed of asphaltum and excelsior. These brickets are employed as a covering to the outer surface of the cavity, and are cemented together with asphaltum. The brickets are secured to the side of the cavity opening by spikes, and are held in place by iron re-enforcements, the portion of the cavity back of the brickets being filled with sawdust, cinders or other material. An especially commendable feature of this method is the unit system employed, and the adaptability of the material to the movements of trees. On the other hand, asphaltum is not a convenient substance to use because it has to be heated. The same objections to completely filling a cavity apply also to asphaltum, although with the use of this material such a practice may not always be necessary.

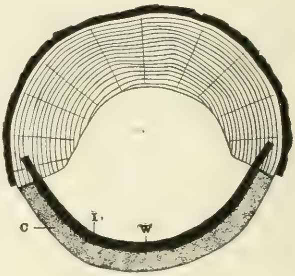

FIG. 55. — Section of tree with cavity illustrating wire and elastic cement method of covering opening. C, elastic cement; W, wire mesh; I, iron re-enforcements.

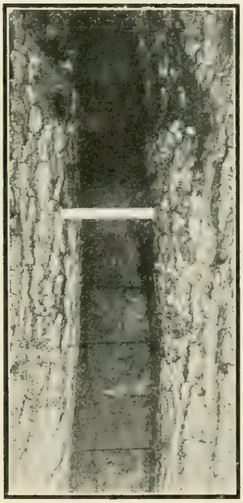

FIG. 56. — Chemically treated wooden block covering of cavity opening, with back re-enforcements of wood. The normal growth of the callus is not disturbed. (After J. A. Davis, City Forester, Springfield.)

Wooden Block Method. — This method of sealing cavities (invented by the writer) has been in use only recently. It consists in the use of chemically treated wooden blocks to cover the opening of the cavities, and makes filling unnecessary. The blocks are of different sizes. Each one constitutes a homogeneous structural unit composed of various cellular elements, similar to those in trees. With this method, as in others, the cavities are cleaned and treated antiseptically, the blocks being used simply to cover the orifice of the cavity and to direct the growth of the callus or healing tissue.

The advantage of wooden blocks for cavity work consists in the fact that the blocks are composed of the same type of element as found in trees. The geometrical arrangement of the various elements, as well as their chemical composition and molecular structure, is similar; moreover, the physical properties — rigidity, elasticity, etc. — are practically identical. The various movements in the cavities of trees resulting from variation in temperature, moisture, barometrical influence, etc., may be better conformed to by the use of this material than by any other yet employed for the cavity treatment.

The blocks should be arranged in the cavity opening so that the radial and tangential surfaces of the structural elements in the blocks coincide in general with those in the tree. It is not necessary to lay the blocks in cement, but in some cases painting the surfaces which will come into contact with one another with an elastic cement is of advantage. The blocks are fastened to the tree by means of special iron braces and held securely by iron re-enforcements. Besides being especially adapted, owing to their physical properties, to use in trees, such blocks are durable, light and easy to fit, and are better adapted to swaying movements and crushing pressure found in narrow cavities than rigid or less plastic substances such as have been used heretofore. The disagreeable and injurious effects arising from bleeding may be taken care of by this method of cavity treatment, and constructive work may be done in winter as well as in summer.

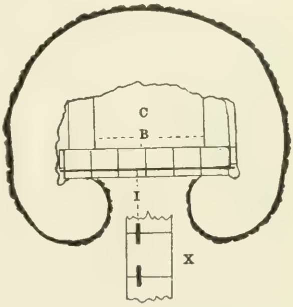

Fig. 57. — Cross-section of illustration shown in Fig. 56. C, cavity; B, chemically treated blocks; I, iron re-enforcement in grooves; X, longitudinal section of blocks.

Tree Guards.

There is almost no end to the types of tree guards used to protect trees. Some of these are good and others are of little value. The purpose of a tree guard is protection, and the guard should cover the tree to a height of about 6½ feet; it should be as light and as inconspicuous as is consistent with strength and protection; and should allow the tree ample

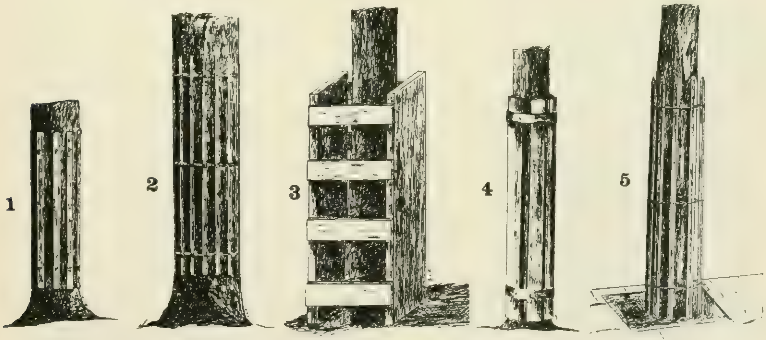

Fig. 58. — Different types of tree guards: 1, wooden strips nailed to a tree; 2, wooden strips nailed to a tree and banded with iron; 3, old type of wooden tree guard; 4, wooden strips banded with iron tightly to the trunk of the tree; 5, similar to 4; all objectionable types.

opportunity for growth without causing injury. The ideal tree guard is durable, easily placed and not easily displaced, inexpensive and neat in appearance. Some tree guards are attached to trees by means of staples or nails, but this method of attachment is objectionable. The old-fashioned tree guard made of wood usually became useless in a few years. However, while it may not have possessed much beauty or permanent utility, it at least showed a commendable spirit and desire for tree protection.

A very cheap and efficient tree guard is used to quite an extent in some places, and is known as the "Clinton Tree Guard." This guard is made of No. 15 galvanized wire, having a mesh three-fourths inch in diameter, all the wire contacts being soldered. This wire may be bought in strips of various widths from 12 to 48 inches, and cut off any length desired, 6 and 6½ feet being the more usual lengths. Strips 12 to 18 inches wide are well suited for small trees. These are rolled up in cylindrical form of the desired diameter, and tied together by a few pieces of copper wire. To prevent the top of the tree guard from chafing the tree the top is protected by wiring through the rough edges of the guard a split piece of discarded rubber hose. Use is also made of insulated wires or springs placed diagonally through the top of the guard to hold it away from the tree. The great advantage of this guard is its cheapness, but it is made of heavy wire firmly woven, and answers the requirements very well. This wire is made by the Clinton Wire Company, Clinton, Mass., and costs about 4½ cents per square foot. (See Fig. 60.)

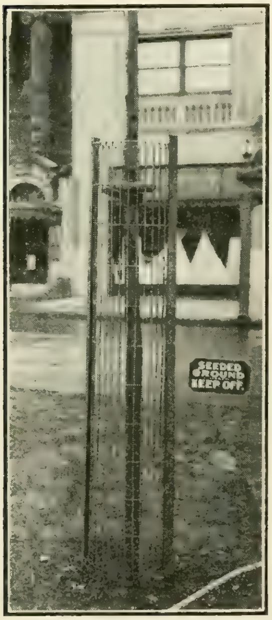

FIG. 59.—Effectual tree guard used on Boston Common. The wire guard is re-enforced by pointed angle irons driven into the ground.

A re-enforced wire cloth guard manufactured by the Wright Wire Company, Worcester, Mass., has recently come into use. It is made from close mesh wire similar to that of the Clinton guard, but is re-enforced with flat metal strips. This re-enforcement is considered a valuable innovation because even heavy wire mesh is likely to crumple up with hard usage, and becomes ineffective as a tree guard. The re-enforced metal edges are provided with holes for the purpose of stapling the guard to large trees. (See Fig. 61.)

One of the neatest and most durable tree guards is shown in Fig. 59. It consists of an open-mesh, heavy-wired guard supported by a piece of angle iron on either side driven into the ground. The angle iron acts as a re-enforcement and holds the guard in place. The use of any guard around trees is more or less of a nuisance, but at the present time they have to be applied to street trees. Planting inside of the sidewalk or on wide tree belts will obviate much of the use of tree guards in the future.

FERTILIZING TREES.

Trees, like agricultural crops, respond to tillage and treatment with fertilizers and manures, but there are only meager data relative to the specific effects of the various chemical constituents in fertilizers on shade trees. From what is known regarding their effects on other crops, and from their limited use on trees and shrubs, it is evident that they may be applied with a reasonable degree of success.

Wood ashes have been used to some extent for treating shade trees, also bone meal, nitrate of soda and potash in the form of muriate or sulfate. Any good complete fertilizers, such as those adapted to lawns, should prove valuable for trees. Wood ashes, which are not so easily obtained as formerly, are of benefit to lawns, and there is no reason why they should not prove suitable for trees. A certain amount of nitrate of soda, at the rate of 150 to 200 pounds per acre, may be used to good advantage, but care should always be used not to apply it too freely. The nitrate of soda stimulates wood production, and, like lime, helps to give a deeper color to the foliage; but an excess produces symptoms of malnutrition in many crops which usually takes the form of an abnormal development of foliage. Bone meal is slow to become available, but it does not injure plants when applied freely, and makes a good fertilizer. Pulverized sheep and cow manure are valuable lawn fertilizers, and even though the price is rather high for the plant food contained, they supply organic matter and therefore have an especially beneficial effect on the soil. They can be applied freely without danger of harm.

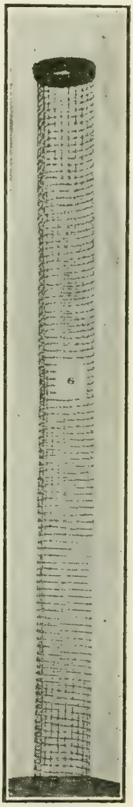
FIG. 60. — Clinton tree guard, with hose protection at top.

While trees will respond favorably to judicious treatment with fertilizers, it must be borne in mind that no fertilizer can take the place of cultivation. Fertilizers should be applied where the feeding roots are located, and these are confined largely to an area corresponding with the spread of the foliage and not close to the trunk of the tree, as imagined by many persons. This also holds true for tillage, *i.e.*, the whole area surrounding the tree should be cultivated to some distance beyond the spread of the foliage. As the tree develops in size the smaller feeding roots become less abundant near the base of the tree, although cultivation and feeding have a marked tendency to induce root development wherever they are practiced. All fertilizers should be applied evenly. Spreading by hand is at best a poor method, as shown by the dark green plots of grass on lawns where nitrate of soda has been applied in this way; but when fertilizer spreaders cannot be had the hand method must be used. Another factor to be considered when applying fertilizers to lawn trees is that the grass roots will obtain their full share. Turning under the sod and cultivation of the soil around the tree is of the greatest importance from the very considerable amounts of organic matter added to the soil. Fertilizers applied under these conditions, or, far better, stable manure well incorporated into the soil at the rate of 20 to 30 cords per acre, are of the greatest benefit to the tree, even if it becomes necessary to reseed immediately. In cases where it is inconvenient or undesirable to disturb the soil around a tree, and when the application of fertilizer to the surface does not accomplish the desired results, holes 1 or 2 feet apart and 15 inches deep may be made with an iron bar and then filled at different times with a liquid fertilizer.

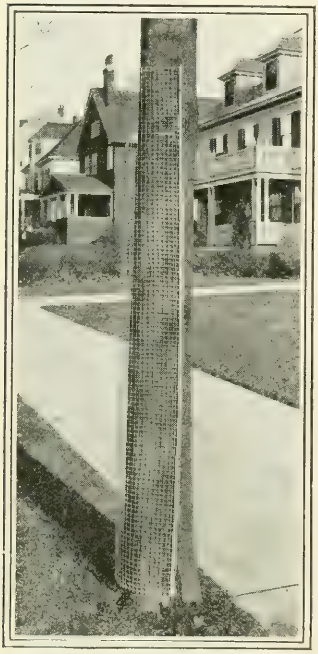

FIG. 61. — Re-enforced wire cloth tree guard, showing edge stiffening with nail holes for attaching to tree. (From the Wright Wire Company.)

There are a number of fertilizer mixtures prepared for shade trees that are undoubtedly of value, but some of them are apparently not based on any expert knowledge of the tree's special requirements.

DISEASES OF TREES.

Trees, like other living organisms, are very liable to attacks from disease, and a tree of any maturity is seldom found perfect in all respects. A disease may be defined as a disorder caused by any failure in or diversion of the normal physiological activities of the organism.

The diseases of plants with which plant pathologists have to deal may be divided into three classes: First, those caused by parasitic fungi; examples, — rust, smut, etc. Second, those brought about by functional irregularities which induce saprophytes (dead wood fungi) or parasites to thrive, such as "damping off," mildew, etc. Third, those of a purely functional nature, pathogenic organisms not necessarily being present; examples, — dropsy or œdema of tomatoes, malnutrition and others. All these types of diseases are found in trees, but the first and second are most common.

Diagnosis of Disease.

A successful diagnosis of disease necessitates a thorough knowledge of the normal and abnormal functions of the organism, together with an understanding of the specific reactions of the plant to various external and internal agencies or stimuli that may affect it. The specific reactions of plants are so little understood as compared with those of animals which have been studied for centuries that it often requires considerable study to make a complete and accurate diagnosis of some of the troubles affecting plants, especially without knowledge of the conditions to which they have been subject. Plants have their peculiarities, like animals, and the large number of different species which are normally adapted to a great variety of conditions and which are likely to be subject to disease renders the problem of diagnosis often quite difficult. The reactions of plants to stimuli are manifold, and much more depends upon the nature of the organisms stimulated, as regards the nature of the response, than upon the particular stimuli giving rise to the reaction. The same agency may produce a variety of reactions even in the same organism, and different agencies will often produce like effects.

It might be difficult to tell whether a particular plant was affected by coal gas, hydrocyanic acid gas, burned sulfur, formalin vapor, or other gases without other evidence than that afforded by the plant, unless the observer possessed a special knowledge of the effect of these gases. But there are distinct symptoms displayed by plants which enable one, after much experience and careful investigation, to determine with some degree of accuracy the exact cause of injury resulting from injurious agencies.

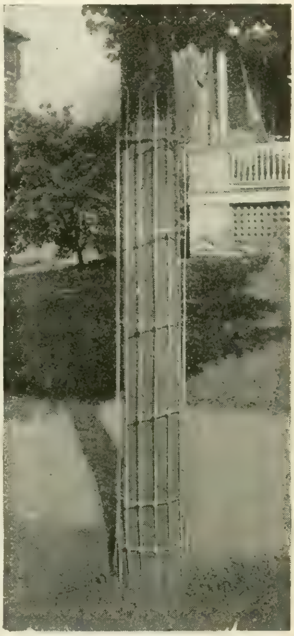

FIG. 62. — Open mesh tree guard with protective springs at top. (From the Wright Wire Company.)

In diagnosing diseases it is first necessary to distinguish between primary and secondary causes. A tree may be subject to borers and fungi, but these may not be the primary cause of the trouble; indeed, they are more often merely secondary effects. A tree may sometimes winterkill and become subject to fungi, but one would not be justified in diagnosing the case as injury from fungi, although in the diagnosis of disease secondary causes are often mistaken for primary ones. It should be borne in mind, however, that no plant ever dies without some definite cause. In determining the health condition of a tree it is important that all the factors in any way concerning it should be well understood; in other words, one should be able to judge of the degree of vigor possessed by the tree. A tree in a vigorous condition has a quite different appearance from one that is less thrifty. In the former case the bark has a certain color and other characteristics by which it is easily distinguished from those in a less healthy tree. This is also true of the branches, twigs and leaves as well as of the general habit of growth.

Finally, in all tree work it is essential that as thorough knowledge as possible should be secured of the structure and function of the tree, its normal and abnormal characteristics, and the causes responsible for health and disease. As a rule, tree workers have little idea of tree structure and function; consequently their diagnoses are seldom correct.

Fungous Diseases of Trees.

There are troubles of a serious nature affecting trees which are not associated with organisms; but by far the most numerous and troublesome diseases are caused by fungi, and occasionally by other types of organisms. The fungi responsible for decayed cavities do the most damage to trees.

There are a great number of leaf spots — *Septoria*, *Cercospora*, *Phyllosticta* and other genera — which affect both our native and introduced trees and shrubs, and mildews are found on almost every tree and shrub. Much careful investigation has been given to the control of plant diseases in general, and valuable results have been obtained from spraying and other methods of treatment. (See Treatment.) The fungous diseases of our agricultural crops have been thoroughly studied, and most of them are of enough importance to warrant systematic treatment every year; but a large number of the leaf spots affecting shade trees are not common enough to do any particular harm, and at least during the past many of them have not been considered worth serious study from the viewpoint of treatment.

Most of the fungi affecting leaves and branches are parasitic; a few are saprophytic, *i.e.*, attacking only dead tissue; while still other forms flourish either as parasites or saprophytes. The root-like mycelia of parasites in most cases penetrate the cells and rob them of nutriment. Often fungi cause distortion of the tissues so that galls and other abnormal growths are formed. They also have acquired the peculiar habit of secreting ferments that dissolve the cell walls. All fungi are capable of producing some injury, but economically considered, treatment is necessary only when the injury greatly retards the growth of the tree or seriously impairs its appearance.

Among some of the commoner forms of fungi that affect shade trees may be mentioned the following: —

Maple (*Acer*). — Leaf spot (*Phyllosticta acericola* C. & E.) forms irregular brownish spots on the leaves of the rock and white maples.

Anthracnose (*Glœosporium apocryptum* E. & E.) is known to cause serious injury to the leaves and shoots of the box elder and maple.

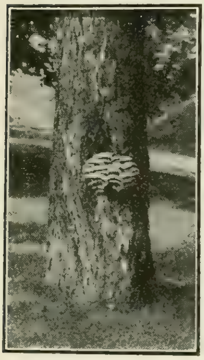

Fig. 63.—Oyster mushroom (*Pleurotus sapidus*) on maple, following injury.

Leaf spot (*Rhytisma acerinum* Fr.) is characterized by conspicuous black spots on the leaves of the red and white maples, but is practically harmless.

Nectria cinnabarina (Tode) Fr., a common fungus characterized by small cinnamon-colored pustules occurring on dead wood, follows winterkilling, sun scald, etc. It is especially noticeable on winterkilled twigs of Norway maples.

Oyster mushroom (*Pleurotus sapidus* Fr.) is a large, edible fungus growing in masses on maples that have been injured by borers and other agencies. A mildew (*Uncinula circinata* E. & E.) sometimes infects the leaves of various maples.

Sun scald and frost cracks are not uncommon on maples. The rock maple is one of the most susceptible trees to sun scorch and "bronzing" of foliage induced by excessive transpiration during dry periods. The red maple is susceptible to winter injury of roots, and like the rock maple suffers from drought.

Horse-chestnut (*Æsculus*). — Leaf spot (*Phyllosticta sphæropsoidea* E. & E.) appears in the early summer, and later causes a conspicuous yellow spotting of the foliage. This disease is more or less common every year. The leaves of the horse-chestnut are occasionally affected with mildew (*Uncinula flexuosa* Pk.), and the winterkilled twigs are sometimes attacked by *Nectria cinnabarina*.

Chestnut (*Castanea*). — This is seldom planted as a shade tree, although it is sometimes seen on country roadsides and on lawns. The chestnut blight, which is so serious and so universally distributed at the present time, renders the use of the species as an ornamental tree out of the question. The chestnut is also affected with certain leaf spots, etc.

Sycamore (*Platanus*). — The tree most likely to be severely defoliated by a fungus is the sycamore. The causal organism is *Glœosporium nervisequum* (Fckl.) Sacc., which affects the petioles and veins of the leaves, causing small black areas on these organs. More or less large portions of the leaves turn brown and the leaf finally falls.

The sycamore is unusually susceptible to winterkilling of the twigs, but in spite of this constant defoliation and twig killing it is a very hardy tree.

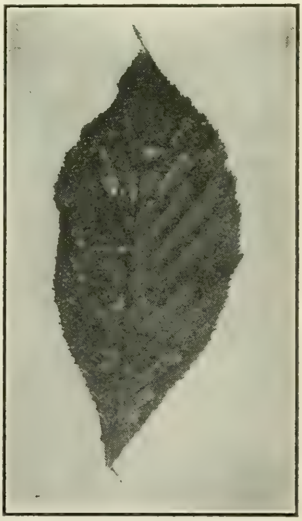

Fig. 64. — Horse-chestnut leaf spot (*Phyllosticta*).

Poplar (*Populus*). — The principal species in cultivation as shade trees are the Carolina poplar, white poplar, Italian poplar and the Lombardy poplar. The Italian poplar is often severely affected with rust (*Melampsora populina* (Jacq.) Lev.), and a mildew (*Uncinula salicis* DC. Wint.) is frequently observed on the leaves of poplars. Anthracnose (*Marssonia populi*

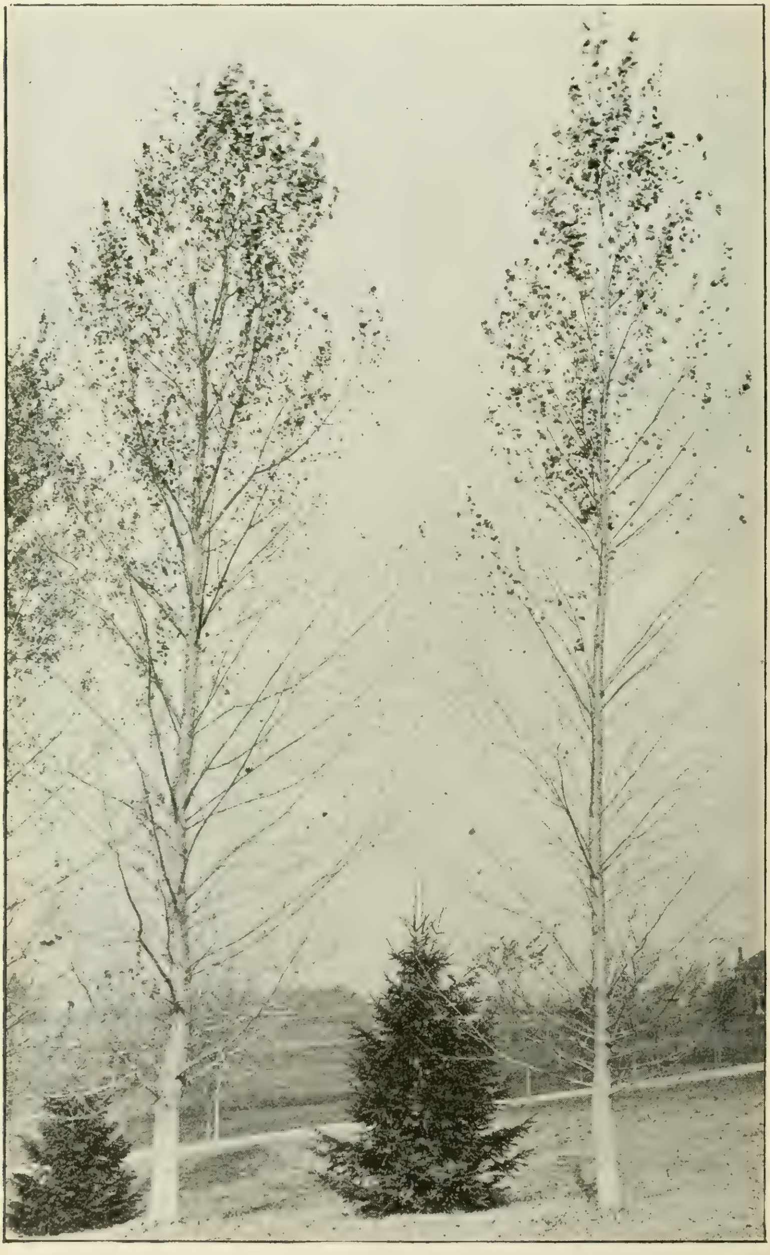

FIG. 65A.—Italian poplars affected with rust (*Melampsora populina* (Jacq.) Lev.). Unsprayed. (After Maynard.)

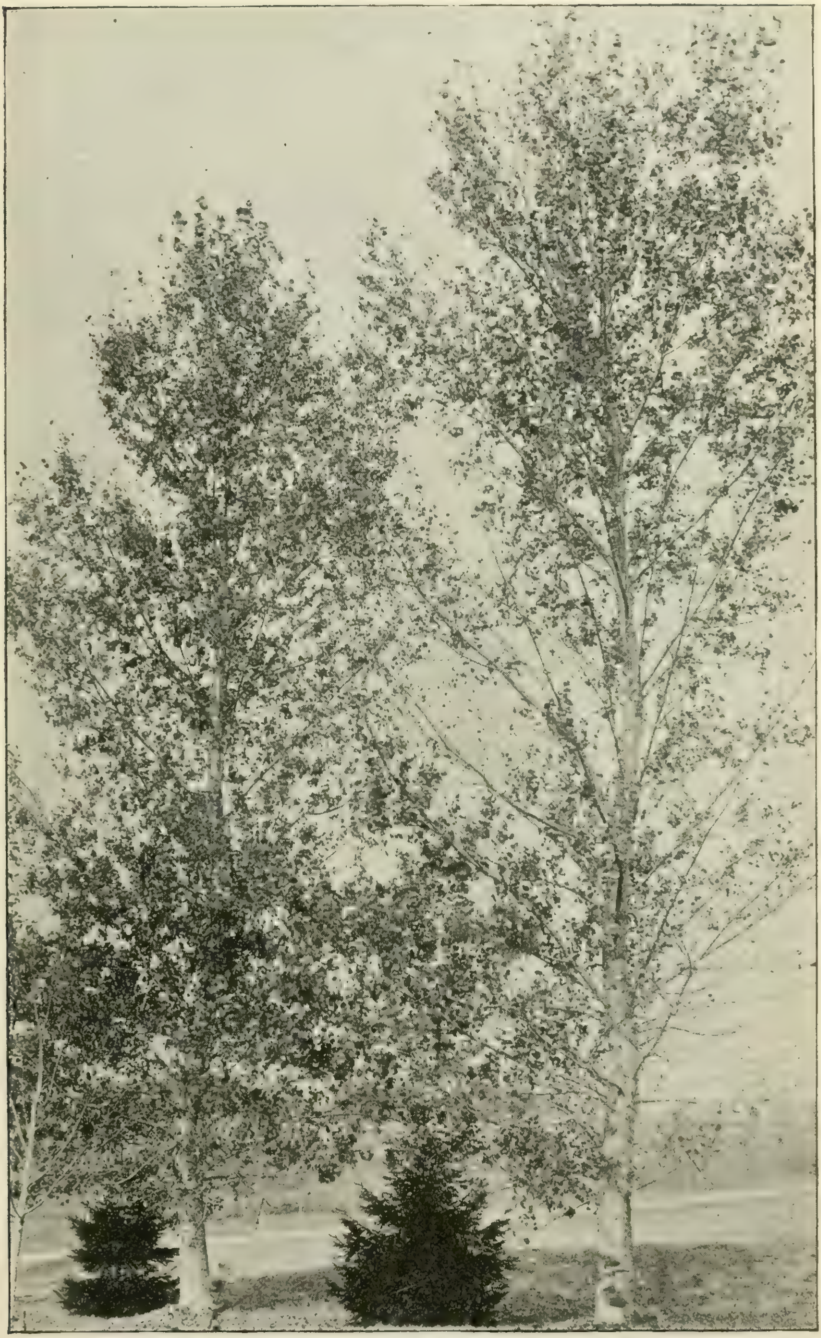

FIG. 65B. — Italian poplars affected with rust (*Melampsora populina* (Jacq.) Lev.). Sprayed with Bordeaux mixture. (After Maynard.)

(Lib.) Sacc.), which attacks the twigs, has been known to cause great injury to many poplars. Poplars are often affected by crown gall and various other diseases.

Oak (*Quercus*). — The oaks are affected by a number of diseases such as *Septoria dryina* Cke., which produces a leaf spot, and by several mildews, *e.g.*, *Phyllactinia suffulta* Reb., *Asterina intricata* E. & M. and *Asterina patelloides* E. & M., *Microsphæra quercina* (S.) Burr. The fungus *Glœosporium nervisequum* (Fckl.) Sacc., which also affects the sycamore, is sometimes found on oaks, affecting the leaf petioles and veins, causing a browning, and, in severe cases, a loss of the foliage. It is most common on the leaves of the shaded branches. *Nectria cinnabarina* (Tode) Fr. also affects the oak. Oak "spangles," little saucer-shaped bodies on the leaves which resemble the work of fungi, is caused by insects.

Hickory (*Carya*). — Two or more leaf spots are found on the hickory, *e.g.*, *Microstroma juglandis* Sacc. and *Phyllosticta caryæ* Pk. Some seasons hickory leaves are quite badly spotted.

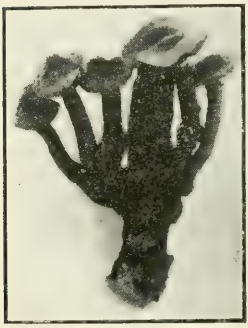

Fig. 66. — *Armillaria mellea* on roots of maple.

Butternut (*Juglans*). — Butternuts are affected by the following leaf spots: *Ascochyta juglandis* Bolish, which is more or less common; *Cercospora juglandis* K. & Sw., *Glœosporium juglandis* (Lib.) Mont., *Marssonia juglandis* (Lib.) Sacc. The butternut has suffered greatly from climatic conditions in the past decade.

Tulip Tree (*Liriodendron*). — The leaves of the tulip tree are sometimes badly spotted by insect work which is often accompanied by fungi.

Sweet Gum (*Liquidambar*). — The sweet gum is affected by a leaf spot (*Septoria liquidambaris* Cke. & E.) and is susceptible to winter injury in the north.

Magnolia. — The magnolia is affected by an anthracnose (*Colletotrichum spinaciæ* E. & H.) which ruins the smaller branches and foliage of the tree. Mildew (*Asterina picea* B. & C. and *Asterina comata* B. & Rav.) is also found on the leaves.

Pine (*Pinus*). — The white pine during the past ten years has been affected by a root killing, which has been responsible for the burning of the leaf tips (sun scorch). Various fungi, such as *Septoria parasitica* Hartig, and *Hendersonia foliicola* Berk., have been associated with this trouble, but both are apparently saprophytes. The terminal twigs of the white pine are occasionally affected with *Phoma Harknessii* Sacc., which causes the death of both the leaves and twigs. *Scorias spongiosa* Schw. forms black incrustations on the leaves and twigs of the white pine in the secretions of the woolly aphis. Rust (*Coleosporium pini*) sometimes occurs on the leaves of the pitch pine.

Catalpa. — The catalpa is affected with the leaf spots *Phyllosticta catalpæ* E. & M., *Cercospora catalpæ* Wint., *Macrosporium catalpæ* E. & E., also with mildew (*Microsphæra elevata* Burr. and *Phyllactinia suffulta* Reb.). A blight disease is recorded which causes the leaves to turn black, shrivel and fall. This is said to be caused by insect larvæ. Two wood-destroying fungi, *e.g.*, *Polyporus versicolor* (L.) Fr. and *Polyporus* (Poria) *catalpæ* are found on the catalpa.

Hackberry (*Celtis*). — The hackberry is occasionally planted as a shade tree, and is affected by two mildews (*Uncinula polychæta* B. & C. and *Sphærotheca phytoptophyla* K. & S.) which are associated with a mite (*Phytoptus*) in producing distortion of the leaves. *Phleospora celtidis* E. & M., *Phyllosticta celtidis* E. & K., *Ramularia celtidis* E. & E. and *Septoria gigaspora* E. & E. are responsible for leaf spots.

Beech (*Fagus*). — A mildew (*Microsphæra erineophila* Cke.) is associated with a mite (*Phytoptus*) on the leaves of the beech. The fungus (*Scorias spongiosa*

Schw.) grows in the secretions of woolly aphis, causing a large spongy black mass on the leaves.

Hawthorne (*Cratægus*). — The leaves of the English hawthorne are affected often seriously with *Entomosporium thumenii* Cke., which produces spots.

Ash (*Fraxinus*). — The stems and leaves of the ash for the past few years have been troubled with a rust (*Æcidium fraxini* Schw.). The worst cases have been found in the vicinity of Cape Cod. The ash is also subject to a leaf spot (*Septoria leucostroma* E. & E.) and mildews (*Phyllactinia suffulta* (Reb.) Sacc. and *Phyllosticta viridis* E. & K.).

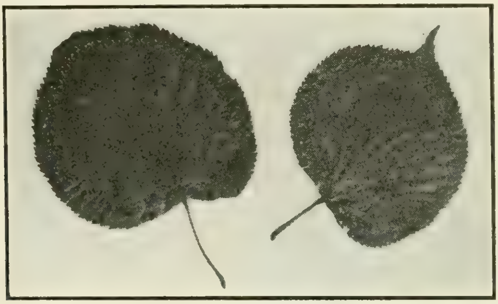

Fig. 67. — Linden leaf spot (*Cercospora*).

Locust (*Robinia*). — The locust is unusually susceptible to borers, and when attacked by them often becomes infected with various species of fungi.

Linden (*Tilia*). — The leaves of the linden are sometimes badly affected with leaf spots, such as *Cercospora microsora* Sacc., which may be largely controlled by spraying. The linden in some locations suffers very badly from frost cracks. The American basswood (*Tilia americana*) is subject to a leaf mildew (*Uncinula clintonii* Lev.) and to the leaf spot (*Cercospora tiliæ* Pk.).

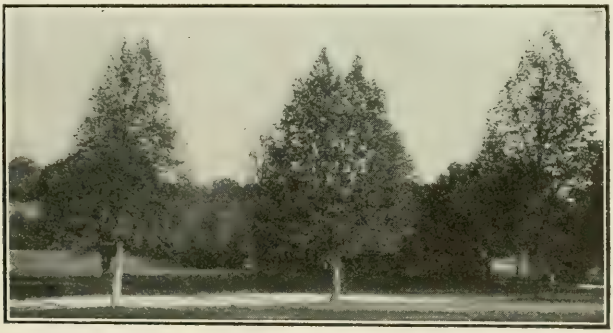

Fig. 68. — Linden tree in center sprayed twice with Bordeaux mixture; others unsprayed.

Elm (*Ulmus*). — The most common leaf spot found on the elm is *Dothidella ulmi* (Duv.), which is characterized by numerous small black spots on the upper surface of the leaves. Another leaf spot caused by *Phleospora ulmi* Wallr. is characterized by numerous small spots from which gelatinous masses exude in damp weather.

This fungus causes defoliation, and sometimes a great deal of injury results. The mildew (*Uncinula macrospora* Pk.) is found on elms, and *Taphrina ulmi* Johan. is found on *Ulmus montana* and *Ulmus campestris.*

The American elm is very susceptible to drought and winterkilling of roots. Frost cracks are also rather common on the elm, and from these and injury from borers the elm bleeds rather freely.

Sun scald, sun scorch, "bronzing" and various types of winter injury, — such as root killing, death of buds, twigs and branches, frost blisters and frost cracks, — drought effects, "staghead" from various causes, and many other troubles not caused by organisms, are quite commonly found on trees.

There is also a sooty mold that grows in the "honeydew" secreted some years quite abundantly by aphids on various species, which sometimes causes considerable retardation of growth. The honeydew is usually washed off the leaves by rains before it does very much harm, but occasionally, in periods of drought, the concentrated sticky covering remains on the leaves long enough to plasmolyse the cells, causing a mottled appearance of the leaves.

Wood-destroying Fungi.

There are a great number of fungi that may be found on dead wood following various injuries caused by sun scald, insect work, fires, illuminating gas, oil sprays and other agencies. Some of these parasites attack the dead bark and penetrate living tissues of the host, destroying the cell structure, and others are found in the heartwood. By far the largest number of wood-destroying fungi, however, are saprophytic in nature, and find congenial conditions only on dead tissue or that which has become weakened from some cause. These fungi produce different chemical and mechanical effects on the tissues, depending upon the nature of the host and of the attacking organism.

A great many of the fungi that attack wounds are capable of producing cavities, although the heartwood fungi are the chief offenders in this direction. These wood fungi are the most insidious enemies of trees, and quite often no trace of their work is discovered until a great deal of injury has been done. They penetrate the tissues slowly and persistently, and the decay is usually so well hidden from sight that the damage does not appear until the injured tissues are removed with mallet and chisel.

While the wood-destroying fungi are responsible for much injury to trees, fortunately it can be prevented by the antiseptic treatment of wounds; and if the decay has progressed until cavities are formed, these should be thoroughly cleaned and disinfected. The great amount of tree work done during the past few years has demonstrated that the careful removal of infectious material from cavities, followed by thorough antiseptic treatment of the cavities, has been very successful in arresting decay and preventing further injury.

Some of the more common wood fungi are given in the following list. This list is by no means complete as there are innumerable deadwood species belonging to many different genera which it is unnecessary to give. Even some of those listed, *e.g.*, the common birch *Polyporus*, are seldom if ever found except on dead trees.

Most of the wood-destroying fungi develop conspicuous fruiting organs that make them easy to identify. Molds and bacteria are also responsible for hastening decay in trees, often preparing the way for other organisms.

Armillaria mellea Vahl. — A parasite mushroom affecting the roots of maples, oaks and other trees.

Dædalea quercina (L.) Pers. — Occurs in wounds and on dead tissues of the oak and chestnut.

Fomes igniarius (L.) Gillet. — False timber fungus. This is responsible for a heartwood rot common to a large variety of trees, such as maple, oak, hickory, poplar, beech and others.

Fomes rimosus Berk. — Common on the black locust, where it forms large, conspicuous fruiting bodies.

Fomes fomentarius (L.) Fr. — Occurs on the beech and yellow birch, probably as a saprophyte.

Fomes applanatus (Pers.) Wallr. — A deadwood fungus often following injury from fire, etc.

Fomes pinicola Fr. — Causes a decay of conifers.

Hydnum septentrionale Fr. — A large, creamy white growth occurring on wounds of rock maple.

Pleurotus sapidus Fr. — Oyster mushroom (edible). Occurs on maples, elms, etc., injured by borers and on neglected wounds.

Polyporus sulphureus (Bull.) Fr. — Red heart rot. Occurs on various trees, such as oak, maple, locust and conifers. Fruiting bodies consist of a series of sulfur-colored shelves overlapping one another and forming a large, round mass.

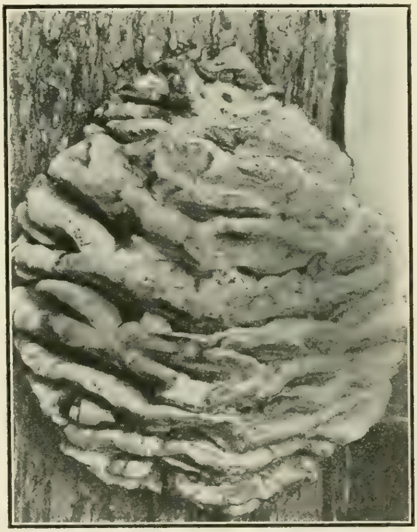

FIG. 69. — *Hydnum septentrionale.* (After E. A. White.)

Polyporus betulinus (Bull.) Fr. — Common on dead birches.

Polyporus gilvus Schw. — On deadwood.

Polyporus nigricans. — A wound and heartwood fungus.

Polyporus borealis (Wahl.) Fr. — A wound parasite on species of hemlock.

Polystictus versicolor Fr. — One of the most common fungi, found on a great variety of trees and cut timber. Very destructive as a saprophyte, and as a wound parasite causes injury to catalpa.

Polystictus pergamenus Fr. — Common on trunks of trees following fires.

Schizophyllum commune Fr. — Common on trees injured from various causes.

Stereum frustulosum Fr. — Causes decay to trunks and occasionally found in wounds, etc.

Slime-Flux.

This trouble is common to trees like the elm, maple, yellow birch and apple. It is associated with frost cracks, injury from lightning, splitting of the trunk, defective pruning, etc., and is not uncommonly found in cement-filled cavities. Slime-flux is characterized by the exudation of a slimy, discolored sap from wounds. This exudation of sap is contaminated with various forms of algæ, bacteria and fungi, and occasionally with low forms of animal life, all of which give the sap a sour odor. This fermenting mass is apparently poisonous to vegetation, since it will kill the grass upon which it falls, and also causes injury to the bark and underlying tissues of trees. The whitish appearance given to the bark by the slimy sap often persists for some time after the flow has stopped.

Bleeding wounds often prove injurious to trees, and are very difficult to treat. The bleeding can usually be stopped when it follows defective pruning, as it often does in the elm. Sometimes wooden plugs nicely fitted and driven into the wound firmly will prevent bleeding, and in some cases the tissue may be cauterized by heat. Cement should not be used in cavities that show a tendency to bleed.

Treatment of Fungous Diseases of Trees.

The methods of treating fungous diseases are numerous, but undoubtedly in the future different, as well as simpler, cheaper and more efficient, methods will be used. The use of antiseptics in the treatment of wounds and cavities caused by the worst enemy of trees, — *i.e.*, the wood-destroying fungi — is absolutely essential in controlling this type of diseases.

Little attention has been given to the treatment of the many leaf spot diseases of trees and shrubs, but from what has been already accomplished along these lines we are justified in assuming that these spots can be controlled largely by spraying; for example, trees like the linden, which often becomes badly infected with a leaf spot, are much benefited by spraying. A linden tree,[1] sprayed twice during July and August with Bordeaux mixture, retained its leaves ten days later than trees unsprayed, and the amount of leaf spot was materially less on the sprayed tree. (See Fig. 68.) The leaf spot *Entomosporium* affecting the English hawthorne may be controlled, according to our observation, by spraying with Bordeaux mixture; and there are many other shade-tree leaf spots that yield to this treatment. In many cases, however, it is a question whether the trees are worth the expense and trouble of treatment.

All the rusts are difficult to control, and it is doubtful whether some of them at least are worth treatment. The rust affecting the Italian poplars (*Melampsora*), which at times has been more or less serious, was held in control quite effectively by Prof. S. T. Maynard,[2] who sprayed for this trouble with Bordeaux mixture many years ago. This rust affects the lower foliage, usually when the dew is most abundant. Infection is sometimes so severe that it destroys the twigs and branches. However, the use of Bordeaux mixture as a spray for ornamental trees is objectionable on account of the discoloration of the foliage, and some prefer the fungus to the unsightly foliage. If possible, some less objectionable spraying material should be employed for ornamental trees and shrubs. Although Bordeaux mixture has proved after many years' trial to be the best all-round summer spray for leaf spots, of late the diluted lime and sulfur solution is being substituted for it with more or less good results. Lime and sulfur applied to dormant trees for the San José scale has proved invaluable as a means of controlling leaf spots, and in some cases it can undoubtedly be used to advantage for certain fungi, such, for example, as the *Glœosporium* infection of the oak and sycamore. It should be applied in late winter before the leaves have begun to appear.

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[1] Mass. (Hatch) Agr. Exp. Sta. Rept. 15, 1905.

[2] Mass. (Hatch) Agr. Exp. Sta. Bul. 25, 1894.

A valuable preventive treatment for fungous infections of trees, in some cases at least, consists in burning the leaves each fall. This is especially valuable with *Rhytisma*, common to maples, for this fungus does not mature its spores while the leaves are on the tree, and burning the contaminated leaves would lessen the chance of infection.

Finally, attention should be given to keeping trees in a healthy condition. Countless examples could be given of the lessened chances of infection possessed by a healthy tree.

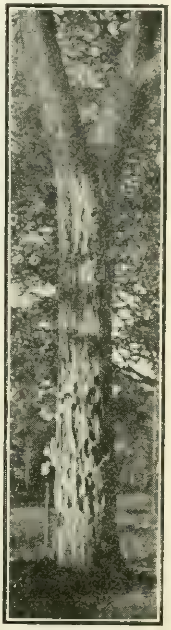

FIG. 70.—Elm tree showing pitted trunk associated with borers. Often observed on trees under uncongenial conditions.

WINTER INJURIES.

Injuries resulting from low temperature are common and often cause considerable damage to vegetation. Whether a species is native or introduced it is likely to suffer from winter injury if the proper condition prevails, but plants introduced from regions where the climate is mild are more likely to suffer from the effects of severe cold, although this does not always follow. Moreover, plants grown out of their customary habitats, or under uncongenial conditions, become more susceptible to winter injury. The red maple, for instance, which usually grows in wet places, becomes more susceptible to winter injury when grown in a dry situation, and the same holds true for other swamp species.

Winter injury is often restricted geographically, although during some seasons it may be quite universal. The same type of injury may also be more common, as well as more serious, in one locality than another. The effects of winter injury to trees may also be local, *i.e.*, only the branches or buds or flowers will be affected; or, again, it may be confined to the roots or other portions of the tree. The apple, pear, quince, peach and plum, various shrubs and vines and small fruits are often injured severely both above and below ground from winterkilling, and much loss results to agriculturists.

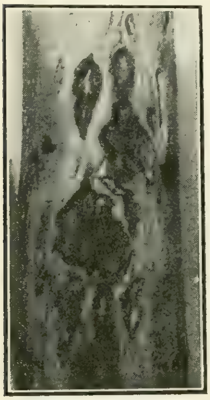

FIG. 71. — Same as Fig. 70, with bark removed, showing characteristic sculpturing.

There are several types of injury resulting from low temperature which may be easily distinguished, and which occur almost every year, such as winterkilling of the roots, of the trunks, branches, twigs and buds; also injury to exposed roots; to the cork cambium, resulting in exfoliation of the outer bark; and frost blisters, causing subsequent defoliation.

Winter injuries are not always the result of severe cold, but follow from a combination of factors. Even the temperature of a comparatively mild winter is sufficient to cause much injury to trees and vegetation in general if the preceding summer and fall have been unfavorable for normal plant development. A very dry summer affects the normal growth of vegetation, and if a warm and unusually wet fall follows such a period the plant will go into the winter resting stage under abnormal conditions, and may therefore possess little power of resistance to cold.

Some of the conditions which underlie winterkilling are as follows: —

Severe cold, causing frost to penetrate to a great depth.

Sudden and severe cold following a prolonged warm spell in the fall, in which case the wood tissue is tender and immature.

Conditions which favor a soft growth and immaturity of wood. Various causes may be responsible for this, such as growth in a low, moist soil, too heavy manuring or fertilization, or absence of sufficient sunlight.

General low vitality, caused by insect pests and fungous diseases and lack of moisture in the soil.

Insufficient soil covering, such as lack of organic matter, light mulching and snow covering in winter.

Location in unusually windy and exposed places, etc.

Winter Injuries of Roots.

During the past decade an unusually large amount of injury has occurred to trees through the northeastern portion of the United States as a result of root killing. Innumerable orchards, small fruit plantations and various ornamental plants have suffered, and forest and shade trees form no exception. This injury has been more severe in New York and Ohio than in New England. The trees most severely affected by root killing are the white pine, black oak, white oak, ash, red maple, white maple, elm, butternut, etc.

There are many symptoms characteristic of this root injury which manifest themselves according to the extent and nature of the injury. If the entire root system is killed the tree dies rather quickly. Sometimes an effort will be made on the part of the tree during the spring, especially if a few roots are still alive, to produce foliage, but the tree soon dies. Then, again, a tree will mature its foliage fairly well, but as soon as the soil becomes slightly dry it will die. In such cases the leaves often turn brown and dry up, and remain on the tree in this condition. There are many cases in which the root systems are only slightly affected, when the tree may live for some time and only show a defective top. This slight affection of the root system is particularly common in red maples, which very often recover in a year or two, the only apparent effect being the somewhat smaller leaves found at the tree's crown. In more severe

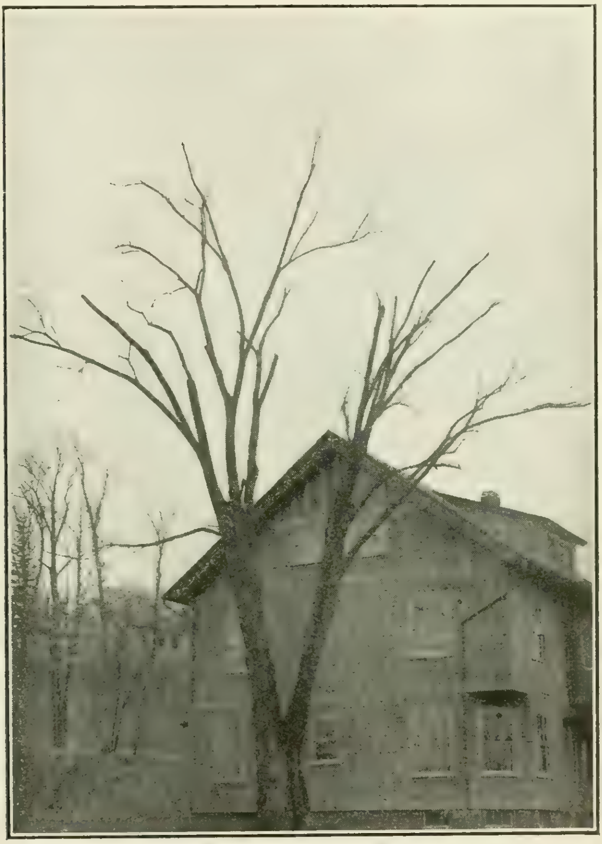

FIG. 72. — Elm slowly dying from defective root system.

cases the top of the tree fails to produce foliage, and the characteristic staghead effect is seen. (See Fig. 82.) We have observed elm trees 4 feet in diameter die suddenly from winter injuries to the roots, but more often death from root injury in elms is a rather slow process, the branches dying at the top and usually presenting the characteristic staghead appearance.

Elms and black oaks often show the results of root injury by tufted foliage effects, especially when much of the upper part of the tree is dead. The few remaining live branches produce numerous large leaves, — the result of an unbalanced relationship between the root system and the upper portions of the tree. In all cases of root injury those portions of the tree farthest away from the water supply, or, more properly, those which are in less direct communication with the main or principal channels of translocation or mobilization, are affected first. In trees naturally developing single leaders, such as the rock maple, the tops die back first, whereas in the elm, which has several leaders or branches located more or

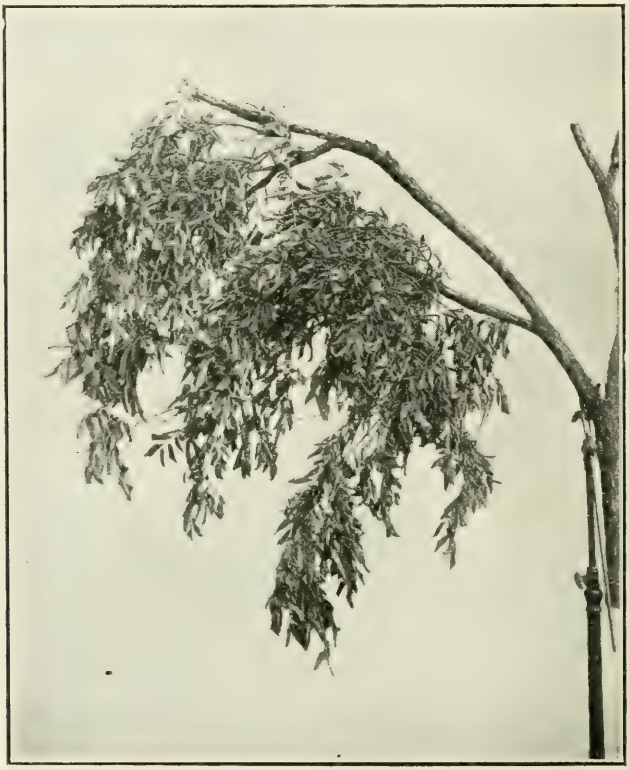

FIG. 73. — Elm branch with tufted foliage, resulting from winterkilling. A large percentage of the branches on this tree are dead.

less alike as regards water supply, each branch is likely to be affected similarly. In evergreen trees possessing a defective root system, sun scorch or burning of the tip of the leaves sometimes follows. This is often serious and may cause a loss of all the foliage, and later the death of the tree (white pine blight).

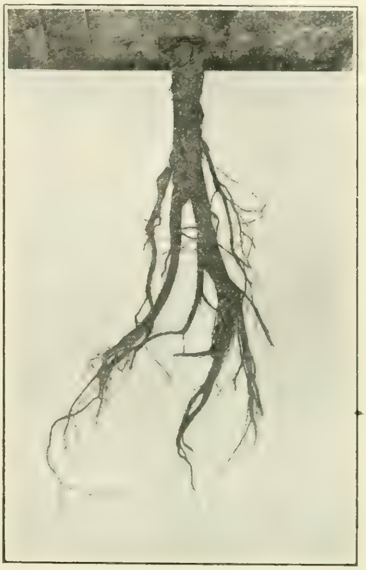

FIG. 74. — Winterkilled root from elm tree. Note lack of fine fibrous roots, which have died.

Many small fruits, grape vines, etc., quite commonly suffer from winterkilling of roots. Plants affected in this way will leave out in the spring, set their fruit and then usually die before it is matured, demonstrating that the maturing and ripening of fruit acts as a severe drain on the water supply of the plant. A fairly large number of shade trees located remotely, or near one another, have died from winterkilling of roots in recent years, necessitating considerable outlay in removing them. Trees located on embankments are very likely to winterkill, that portion of the tree towards the embankment being affected. Roots growing under favorable conditions are less likely to be affected than those growing under poorer conditions, even in case of a single tree. The smaller, younger feeding roots are usually most severely affected, and there is a marked tendency in some species for the roots continually to die back to the trunk when the terminal root system is affected. In these cases numerous new lateral roots are often formed, but as the dying back continues, these are eventually involved. Various fungi soon attack any part of a tree dying from root injury. Later, the bark falls off, but deterioration is not so rapid as in trees killed by other causes.

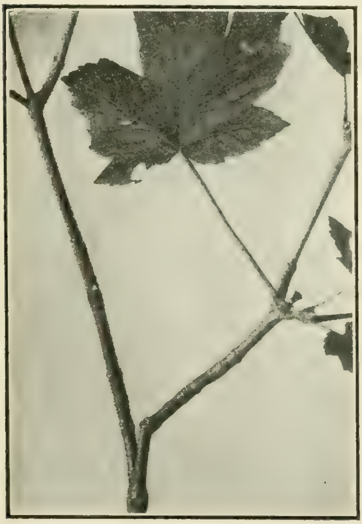

FIG. 75. — Norway maple affected with *Nectria cinnabarina* following winterkilling of twigs.

While the symptoms of dying back resulting from winterkilling of roots are not alike in all cases, they are easily distinguished from those of troubles caused by other agents, such as gas poisoning, etc. In the majority of cases trees showing this staghead effect, whether from drought or winterkilling, die gradually, and even when their death is more or less rapid there are few of the symptoms characteristic of gas poisoning. Trees poisoned by gas usually die and disintegrate rapidly; also the diagnostic features to be found in the tissues of trees killed by gas are entirely different.

Winter Injuries above Ground.

There are numerous cases of injury occurring above ground from the effects of winter, such as the dying back of California privet, various fruit trees and vines, our native alders, white birches, the terminal twigs of trees like the horse-chestnut, Norway maple, sycamore, Japanese maple, and a considerable variety of exotic trees and shrubs. Some of the specific types of winter injury to trees will be best treated under the different names by which they are known.

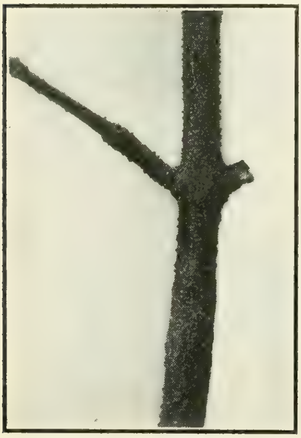

FIG. 76. — Same as Fig. 75, enlarged, showing pustules.

Winter injuries, like other types of injury responsible for the production of dead tissue, are usually followed by various species of fungi, a common form being *Nectria cinnabarina*, characterized by the appearance on the bark of numerous cinnamon-colored pustules, — fruiting bodies of the fungi.

Frost Cracks.

Frost cracks are often seen on many of our shade and fruit trees in winter, and are particularly common to the elm and linden, although occasionally seen on maples. They extend down the trunk for some distance on the sunny side of the tree, and are caused by severe changes in temperature during the winter. Some of our forest trees are also subject to frost cracks; *e.g.*, the striped maple when planted in the open, but never in the dense forest, its native habitat, showing that the trunks of certain trees need to be shaded. Frost cracks open in winter and close more or less in summer, although quite often they never succeed in entirely healing over. In the spring they usually bleed profusely, giving forth a sour, dingy-colored sap called "slime-flux," which shows under the microscope various species of fungi, algæ and yeast.

The opening and closing of frost cracks vary with the temperature, barometer and relative humidity, and so closely is this variation allied with meteorological factors that the weather conditions can be determined quite accurately. Sometimes frost cracks open 4 or 5 inches or more in winter and close pretty well in summer. They usually extend rather deeply into the wood.

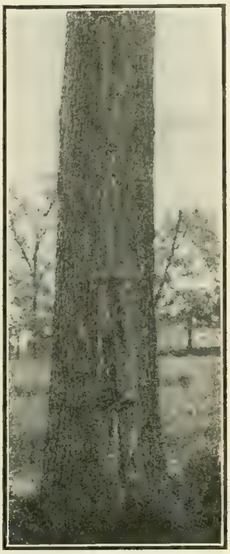

FIG. 77.—Effective method of treating frost cracks by iron staples. (See Fig. 78.)

The best way to treat frost cracks is to staple them together. (See Figs. 77 and 78.) Since the cracks open more in cold weather than in warm, this operation should be done in the spring or summer, when the cracks are more or less closed. Staples made from iron three-eighths to five-eighths of an inch in diameter and 4 to 5 inches wide, with prongs of the same length, are best suited to this purpose. The size of the staples depends upon the nature of the frost cracks to be treated. In making up the staples it is a good idea to have the ends of the prongs bent inward a trifle, as they are more likely to hold. The staples are driven into the tree at a distance of from 15 inches to 2 feet apart, as the case requires, and this is best done by first boring holes about the size of the staples. The bark and wood should be removed sufficiently to allow the staples to be driven in flush with the wood, and the exposed tissue should be treated with some antiseptic substance, such as paint or creosote. If it becomes necessary to treat the cavity of the frost crack it should be done in the winter when the crack is open, and such materials as creosote, coal tar and elastic cement or oakum may be employed for this purpose. Disinfecting the wood is a most important treatment, but filling the crack is of secondary importance and is not absolutely necessary. In our experiments the use of staples in large trees has been successful in holding the crack together so that healing of the tree may follow. If the cracks are not held securely together their constant opening and closing, due to the changes of temperature, rupture the healing tissue and prevent the callus from joining. Trees are sometimes so severely injured by frost cracks that they bleed to death, and we have observed maples that had bled to death in a few weeks from this cause. Occasionally the cracks extend from the very top of the tree down to the base, when there is small chance of the tree surviving.

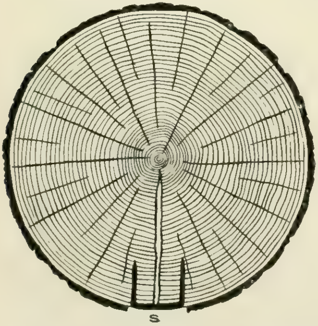

FIG. 78. — Section of tree showing frost cracks and iron staple method of preventing opening, thus facilitating healing.

Winterkilling of Cork Cambium.

As already stated, the effects of low temperature on a tree may be entirely local; *i.e.*, it may affect some particular organ or some one portion of the tree only. Following one of our extremely severe winters a few years ago, elms and some sycamores were found suddenly discarding their outer bark, — a rather unusual phenomenon. This loss of the outer

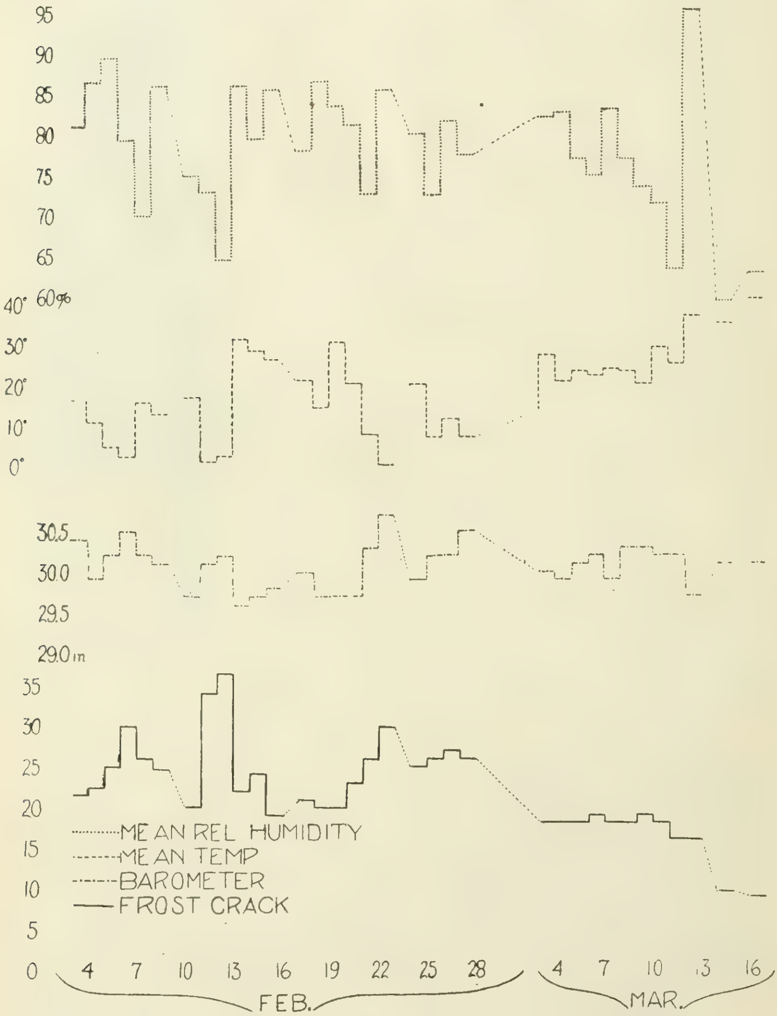

FIG. 79.—Showing curve of opening and closing of frost cracks in elm trees. The lower curve represents the variations in the opening and closing the others represent the mean relative humidity, mean temperature and barometer in the order named.

bark was brought about by winter injury to the cork cambium, a vital layer located between the outer and the inner bark. It did not injure the tree in the least, since the inner bark and the cambium layer underneath remained unaffected. As the collapsed cells of the cork cambium decomposed, the outer bark became loosened from the tree and fell off in a year or two, covering everything it happened to fall upon with a peculiar reddish powder. A microscopic examination of this powder showed it to consist of disintegrated cork tissue, or lamellæ. This injury to cork cambium from low temperature, although observed here and there, was not common. In one city in New York, however, 50 trees were affected, but in only one or two instances did injury extend to the wood and involve the cambium layer. One large sycamore tree 4 feet in diameter, which we observed, lost all of its outer bark, but is in good condition at the present time. The large section of bark, composed of many annual layers of cork, fell off in a comparatively short time, giving to the trunk an unusual whitish appearance. Occasionally there may be found in our State elm trees in which the cork cambium has been affected by winter temperature, resulting in a subsequent loss of the outer bark. But the exfoliation of small portions of the outer bark of elm trees is not uncommon, and should cause no apprehension.

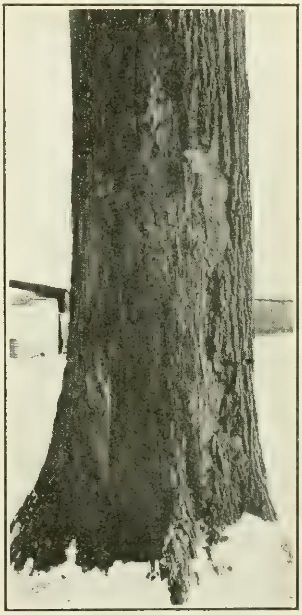

FIG. 80. — Elm tree which has lost its outer bark, resulting from winter injury to cork cambium.

Sun Scald.

Sun scald is a type of injury affecting unripened wood. It is quite commonly met with on rock maples and orchard trees and on some of our wild shrubs. Shade-loving trees are particularly susceptible to sun scald, as may be observed in any forest clearing. For instance, the moose maple, a shade plant, seldom scalds in its native habitat, but when timber is removed and the sun allowed to enter, it is affected. This tree is undoubtedly the most susceptible of any to sun scald.

On the apple sun scald is often associated with canker (*Sphæropsis*). White pines also, when thinned too freely, will sun scald severely on the trunk. Many shade trees in our State show injury from this cause, the trouble being more common in some localities than in others. In one section of a city in the eastern part of the State more than 60 per cent. of the maples were found to be suffering from sun scald. The scars, which were confined to the trunk, were invariably on the sunny side of the tree, being more commonly on the southwestern side, where the maximum temperature was usually found.

Sun scald does not usually involve the whole trunk of large trees, but in many cases, particularly small maples, the whole tree will suffer. A few years ago, in a comparatively short distance on one street, 16 maples had died from sun scald, and at one time our wild cornel (*Cornus circinata*) suffered severely from this trouble, many of them never recovering.

Quite often young rock maples will show only small spots affected by sun scald, proving that the injury may be only local, as in the case of the apple, on which tree sun scald often takes the form of collar rot. Sun scald on apples is often confined to the shaded branches, and sometimes occurs on severely pruned or dehorned trees.

In some cases sun scald will be found on tree roots and root buttresses exposed by regrading. Instances of this class of injury have been noted, particularly in the case of hickories. Any regrading necessitating the exposure of roots should be done in the spring rather than in the fall. Piling soil too high around the base of young apple trees produces injury, and frequently results in girdling the trunk and the death of the tree.

Most cases of sun scald are followed by an outbreak of *Nectria cinnabarina*, as is often the case with winter-killing. The treatment of sun-scalded areas should consist in scraping the wood, after removing the bark, and treating with some such antiseptic or preservative material as creosote and coal tar, or thick paint.

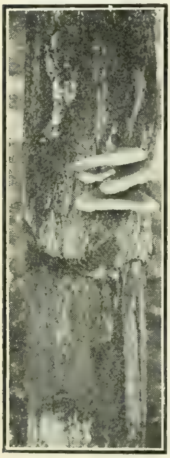

FIG. 81. — Fungi following attacks of borers on rock maples, resulting from extreme drought.

DROUGHT.

The unprecedently long period of drought of the past five or six years has been an unusually severe drain on vegetation in general. While the rainfall records for this period show quite a marked falling off from normal, it should be borne in mind that rainfall is only one factor in producing drought, and the amount of rainfall seldom gives a correct idea of the severity of drought. So far as crops are concerned, the amount of water contained in the soil is a most essential factor. This is determined not only by rainfall but by the amount of water withdrawn from the soil by surface evaporation and the transpiration of plants. Enormous quantities of water are removed from the soil by these processes, which are much influenced by sunshine and wind. The amount of water transpired by the foliage of trees varies greatly from day to day. When the meteorological conditions are favorable for this function, as they usually are during hot, dry seasons, enormous quantities of water are taken from the soil into the air; consequently the soil may contain much less water than rainfall records would indicate.

One of the common effects of drought on trees is the premature yellowing and falling of the leaves. Quite often, however, as in the case of the elm, the leaves fall off in large quantities without turning yellow, and the not unusual habit of this tree of shedding its terminal branches may be associated with drought. During dry periods the leaves of rock maples often sun scorch, particularly when strong winds are blowing; and what is known as bronzing of the foliage is associated with a lack of water.

Drought in summer interferes with the development of the tissue, thereby affecting the growth of trees. In times of unusual rainfall a renewed activity often takes place in the fall, when many shrubs will begin to blossom again and throw out new leaves. The result, especially in very cold winters, is a susceptibility to winterkilling on the part of the tissue.

Drought is responsible for many pathological conditions in trees. Many of them, such as the rock maple, the European cut-leaf birch, the white ash and others, become weakened and therefore more susceptible to attacks from borers and in some instances to scale insects, as a result of which many trees die. When plants enter the winter resting period after a drought in the fall they are very likely to become victims of winterkilling.

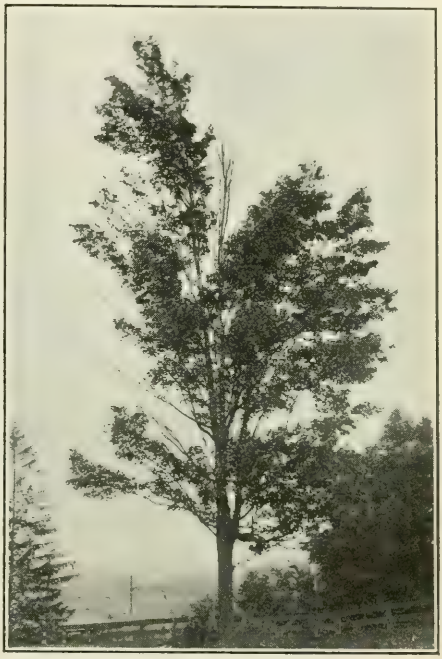

Fig. 82. — Showing maple with staghead effect.

Severe drought affects the roots of trees, which are unable to thrive with so little soil moisture for any length of time, especially when the soil is dry as powder to a considerable depth. During the past three years the root systems of numerous maples, elms and other trees have been severely affected by drought, as shown by the cases of staghead and the unusually large number of trees that have died during this period. Trees affected by severe drought sometimes die suddenly, but more often they linger in a dying condition for a few years. The wood of trees like the elm, when dying from drought, is invariably quite brittle, owing to the fact that the decreased water supply from the roots causes a transformation of the sapwood into hard wood.

Shade trees growing in dry situations may be greatly helped over periods of drought by cultivating around them, by supplying water, or by turning under the sod and applying manure heavily. Planting a crop around the tree is also beneficial, but when this cannot be done conveniently, water may be supplied to the roots through numerous holes 1 or 2 feet apart and 12 or 15 inches deep, driven in the soil by means of an iron bar. In applying the water it is important that the feeding roots be reached, and perhaps a small amount of plant food may be added at the same time. Sometimes wells are installed near the feeding roots of trees; and tile aqueducts can be placed under trees at the time of planting, through which water can be supplied to the roots of the tree. This latter method would prove valuable in periods of drought for trees like the European birch and others which are greatly weakened by any deficiency in the water supply.

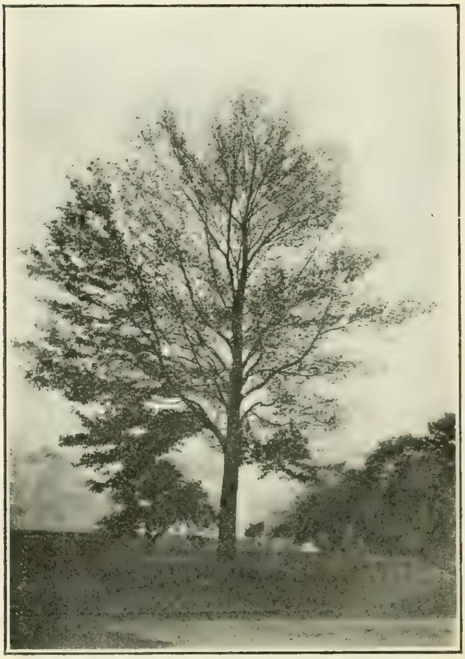

FIG. 83. — Red maple, alive with inferior foliage at the top.

SUN SCORCH AND BRONZING OF LEAVES.

Sun scorch is a physiological trouble characterized by the wilting and burning of the foliage of several species of trees during the spring and summer. Sun-scorched leaves often present only a few dead, brownish areas located on the margin of the leaves, or comprising more or less large areas of dead tissues between the leaf veins. When a strong wind is blowing the dead areas often disappear and the leaves present a lacerated appearance.

Sun scorch is caused by severe warm winds when the soil moisture is low. It is more common in the spring and early summer, when transpiration is at its maximum, the leaves transpiring more water than the roots can obtain from the soil. As a result they become wilted, and those parts of the leaves which fail to recover from the wilt die. Identical troubles affect agricultural crops, ornamental shrubs, etc., although known by different names. Tipburn of potatoes and onions, topburn of lettuce and the so-called winterkilling of conifers and rhododendrons in the spring are in reality sun scorch.

The rock maple is most commonly affected by sun scorch, although other trees suffer to a certain extent. There is seldom a season that this species does not sun scorch, and during the summer of 1913, 30 per cent. of the trees in some localities were sun scorched so badly that the foliage presented a decided reddish brown appearance.

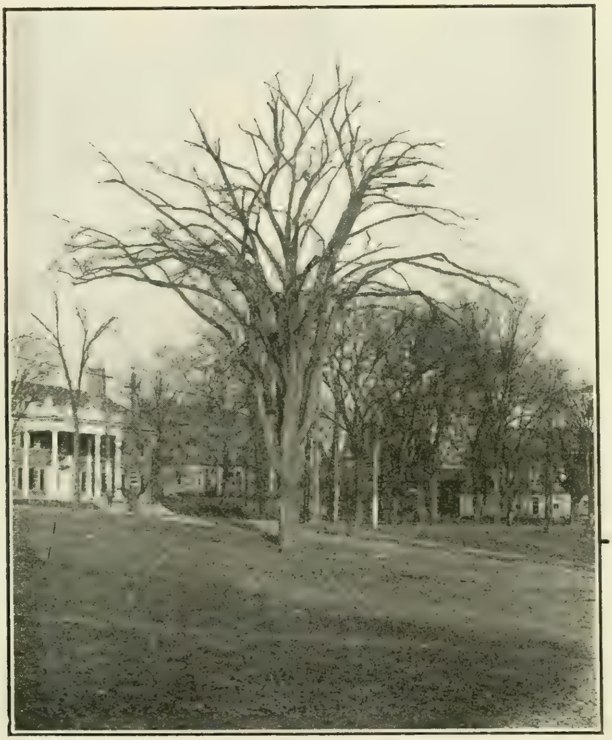

Fig. 84. — Elm tree showing staghead from defective root system. Note dead, stubby branches at the top.

As already stated, strong winds are one of the prime causes of sun scorch. A few years ago in May there was a wind from the northwest which blew at the rate of 71 miles per hour, and as a result many thousands of rock maples sun scorched throughout the State. Burning in all cases was confined to the northwest side of the tree. The particular winds which cause sun scorch may easily be ascertained, for that part of the tree exposed to the prevailing winds is always the one affected.

Some trees are subject to sun scorch each year. Light, porous soils having little water-retaining capacity are responsible for a great deal of this trouble, as shown by the fact that the white cedar, arbor vitæ, etc., accustomed to wet situations, are quite susceptible to sun scorch when grown out of their natural habitat. There is also reason to believe that in some cases a peculiar chemical condition of the soil or some variation in the root absorptive capacity, which limits absorption, is at the root of the trouble.

We have been observing for a long time maple trees which sun scorch badly each year. During especially severe droughts every leaf is affected, while trees located near by are not in the least injured. The leaves of trees suffering from sun scorch do not usually fall off, but remain alive, although discolored. It is impossible for them to perform their full functions, but little injury results to the tree.

Rhododendrons, arbor vitæs and other conifers often burn in the spring before the frost is out of the ground, when strong, warm, dry winds occur. When they are mulched the frost remains in the ground longer than it otherwise would, and the winds cause more transpiration of water than the roots can supply. Many rhododendrons meet their fate in this way, their death usually being attributed to winterkilling. This can be prevented by removing the mulching early in the spring and allowing the sun to thaw out the frost.

"Bronzing" of foliage is merely another form of sun scorch common in very dry, hot periods. It is not caused by wind, and there is no laceration of the foliage. Examination shows that the cells near the veins and veinlets of the leaves are alive, but those farthest away are dead. This bronzing is caused by a lack of water supply to the cells of the leaves located most remotely from the veins or source of water supply. Like sun scorch, it is associated with excessive transpiration and diminished root absorption. The leaves become a reddish brown or bronze color, the dead tissue giving them this peculiar hue. It is most commonly met with on the rock maple, though other trees sometimes show the same trouble.

Mechanical Injuries.

Although trees possess quite a remarkable power of growth, by means of which they are able under certain conditions to overcome apparently insurmountable obstacles, they do not always make use of this power. When roots and other organs are restricted in some way in their growth, they often lift objects weighing many tons, but when there is opportunity for active tissues to flow around the object, as it were, this more practical and easier method is used. Every type of injury to a tree acts as a stimulus, hence there usually follows an accelerated growth of the tissues around the wounds, which often produces disfigurement.

Under the heading "mechanical injuries" may be described many injuries arising from various causes. The injuries due to wires have been treated in Bulletin No. 156. In cities and towns perhaps one of the most common injuries to be seen on roadside trees is that caused by horses' teeth. Trees located between the sidewalk and the road are especially liable to be gnawed by horses, but the many good types of tree guards to be had make most of this inexcusable. There are statutes which cover such cases of injury, but it is always better for the tree warden or city forester to prevent injury by the use of a tree guard than by resort to courts. Very often trees are injured by being so close to the roadbed that heavy teams come in contact with them and cause abrasions. This is common in large cities where there is a great deal of heavy traffic. Runaways are also responsible for occasional injury, and for all these reasons the ideal location for a street tree is that known as a "tree belt." Many of the modern streets are now provided with tree belts 4 to 10 feet wide or more, situated between the sidewalk and the road. When such space is available it is possible to plant trees some distance from the curbing, preventing injuries from heavy teams and horses' teeth. The most frequent offenders are grocerymen and marketmen. It is their common custom everywhere to leave their horses unhitched in front of a house, within easy reach of any trees located near the roadside. Tree-belt planting prevents this difficulty. If tree belts are not available, it is advisable to plant the trees inside the sidewalk near the highway line, and since on every well-kept avenue there are fertilized lawns, a tree in such a location is under desirable conditions for healthy growth.

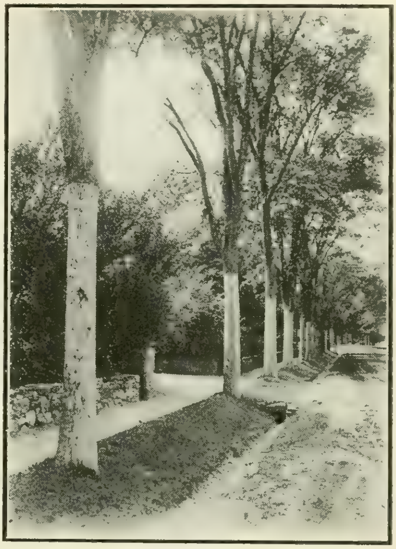

FIG. 85. — Elm trees with bark scraped, illustrating a hideous and useless practice.

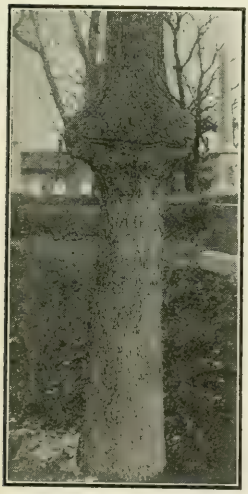

FIG. 86. — Obliteration of signboard on tree, resulting from stimulated callus growth.

Placing signs on trees is another objectionable feature. Since the signs cannot accommodate themselves to the tree's growth, the bark grows over them, causing ugly scars. The same objection holds true of the fastening of other objects, particularly wire fences, to trees.

Some injury to trees is occasionally caused by spurs. Trees have sometimes been severely injured in this way, and as a rule all climbing of trees should be done without the use of spurs. Most of our intelligent and thoughtful foresters and tree wardens never allow them to be used.

Ice is responsible for much disfiguration of trees which cannot easily be prevented. It affects more particularly such soft-wooded trees as the white maple, and greatly mutilates them by breaking down their limbs.

Posting advertisements on trees on country roadsides is another objectionable practice, but this is prohibited by law in Massachusetts. (See page 263.) A great many roots are injured and destroyed by the laying of gutters and curbs, sewers, water and gas pipes, telephone conduits and catch-basins, but at present this seems to be unavoidable.

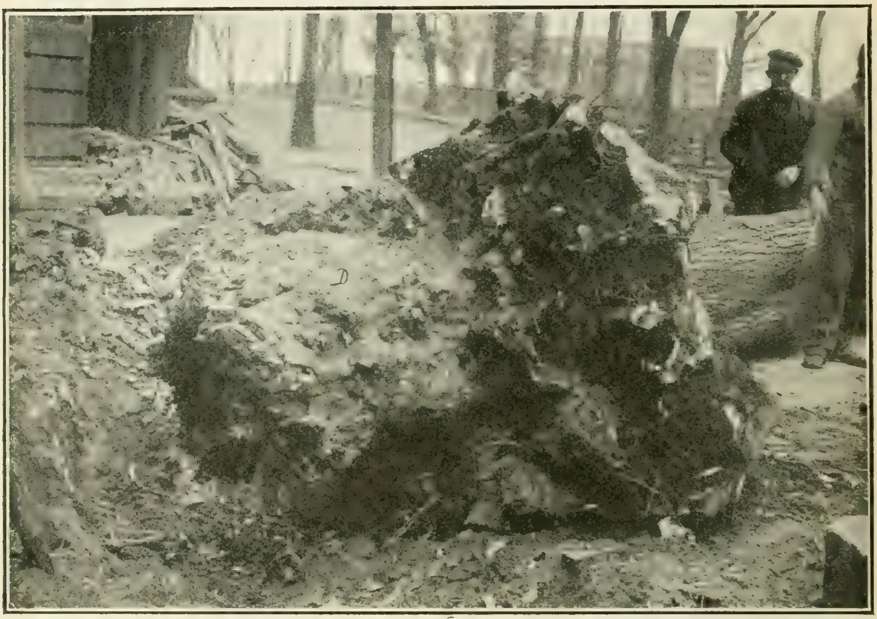

FIG. 87. — Trunk of an elm tree, showing old trunk and new formation of roots.

Earth Fillings around Trees.

The remodeling and regrading of streets, lawns, etc., often necessitate filling in around trees. These earth fillings are usually fatal to trees, no doubt owing as often to the effects of the earth on the bark as to the lack of air to the roots from the deep covering of the soil. We have seen trees growing on a bank with one side of the root system and part of the trunk covered with soil. Those parts covered with soil gradually died, and finally the whole tree died. The maximum depth of soil around the trunk was not more than 8 inches, but the roots were covered for 18 to 20 inches. The soil used for refilling was of a fine texture, — undoubtedly more injurious than a loose-textured soil would have been. In this case the death of the trees was caused by too close contact of the soil with the bark. When a stone wall is first built around the tree at sufficient distance to allow for future growth, to keep the soil away from the trunk, trees filled in to a height of 5 or 6 feet have been known to survive for many years.

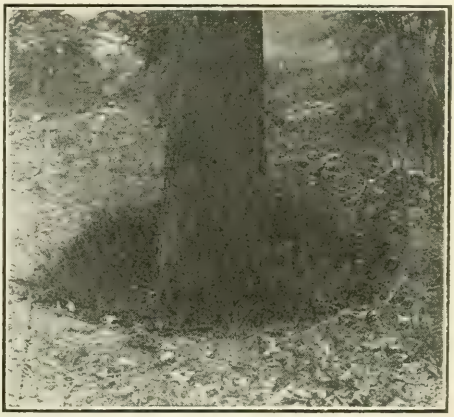

FIG. 88. — Red maple injured by earth filling 1 foot deep.

Some trees are undoubtedly more easily injured by earth fillings than others, but building a wall around them to keep the dirt from the trunk, or even the use of cobble stones, brick or coarse gravel close to the trunk, tends to prevent injury. Banking soil for even a few inches around young trees sometimes causes injury.

There are many instances where trees which have been buried partly up the trunk threw out a new root system nearer the surface of the soil. The tree shown in Fig. 87 had been filled in with soil to a depth of 4 feet thirty-five years ago, and in removing the tree it was found that the old stump and roots were all decayed, but the new surface roots had proved sufficient to support the tree.

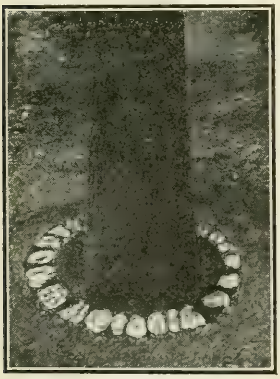

FIG. 89. — Wall built around the base of a tree to prevent injury from earth filing. (See Fig. 88.)

Bleeding of Trees.

A great many trees suffer from bleeding from different types of injury such as borers, lightning strokes, frost cracks, splitting of the trunk, and occasionally linemen's spurs. Often trees filled with cement bleed; and the exudation, containing magnesium compounds derived from the cement together with various microörganisms which thrive in the exuded sap, gives an unsightly appearance to the bark. Bleeding to excess is very injurious. Sometimes the death of trees from this cause is sudden, and in other cases the tree will linger, gradually dying back at the top, and eventually dying. The exuded sap, or "slime-flux," sometimes proves detrimental to the living tissue, as shown by the presence of saprophytic fungi.

Elm trees often show a white streak on the bark, caused by some injury resulting in bleeding, and maples are also quite often affected, sometimes going into a slow decline, followed by death from bleeding alone. These injuries are a difficult class to treat, and at present no satisfactory method is known.

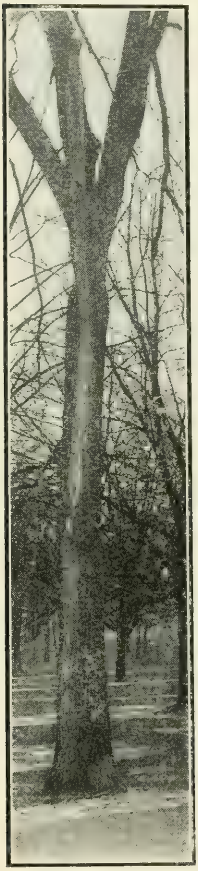

FIG 90. — Bleeding elm. The white streak on the limb and trunk shows the slime-flux.

INJURIOUS CHEMICAL SUBSTANCE.

Kerosene Oil.

Many different oils have been used for spraying insect pests, some of which have proved reliable and others injurious. Kerosene oil can be used on some plants under certain conditions without causing injury, while in other cases it will kill them. A few years ago there was placed on the market a spraying device for the mechanical mixing of kerosene and water in different proportions, but when these materials are mixed mechanically they separate on the tree, and they have been responsible for the death of many trees. The oil soaks into the bark and often reaches the cambium and sapwood, destroying the tissue; and we have seen quite a few shade trees killed by spraying with kerosene and water to exterminate woolly aphis. In some cases every part of the tree touched by the kerosene was injured, while in others the injury was only local, a more commonly noticed condition on thick bark trees, while the former case was invariably restricted to trees with thin bark. The bark of trees killed by the use of kerosene presents a different appearance and develops usually a different type of fungous flora from the bark of trees dying from other causes; besides, traces of the oil, which remain on the tree for a long time, can be detected by the sense of smell. A fair diagnosis of this type of injury may be made from specimens of the bark, but when there are comparatively slight local injuries it is best to examine the tree *in situ.* Even slight traces of oil may be detected by removing small portions of the outer bark on the sunny side of the tree, the sun's heat causing a slight volatilization and perceptible odor.

Gas Oil.

Gas oil, a heavy oil used in the manufacture of water gas, is very injurious to trees when used as a spray. A few years ago several hundred shade trees were severely injured in one of our eastern cities by spraying the trunks with this oil to kill clusters of gypsy moth eggs, it being used without any knowledge of its adaptability to this purpose. (Fig. 91.) The oil quickly soaked into the bark, cortical tissue and cambium, and in some cases extended into the sapwood for one-half to three-fourths of an inch. This injury occurred even on trees with fairly thick bark, killing all the living tissue wherever the oil was applied. While in some instances the trees did not show extensive injury, in others the trunks were 50 to 90 per cent. girdled, and many of the trees died from complete girdling. The most striking feature of this case was the ability of the trees to produce perfect foliage even after serious injury had taken place. One tree was examined whose trunk was girdled for a height of 15 to 20 feet, but this tree persisted in producing foliage for two years after the bark had fallen off. An explanation of this remarkable case consists in the fact that the heavy oil soaking into the sapwood prevented it from checking or cracking, therefore the supply of water from the roots was uninterrupted. The trees treated were elms, different species of maples, which are especially susceptible to injury, and others. The presence of oil in the sapwood in the cases cited above was of the greatest aid in preventing cracking and in helping to maintain the transpiration current and normal foliage, and this bears out the recommendation that tree wounds, very soon after they are formed, should be painted or treated in some way to prevent cracking. It is sometimes necessary to scrape the wound before applying the paint.

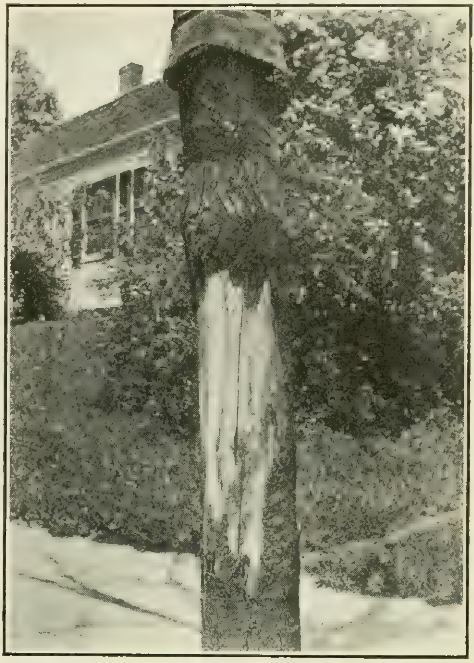

FIG. 91.—Effects of spraying heavy oil on trees. The oil penetrated the bark and killed the tissue.

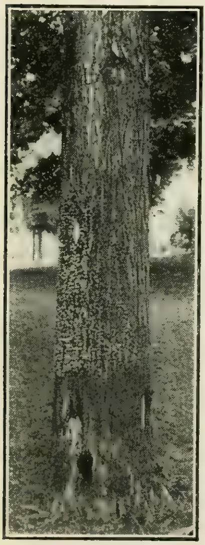

FIG. 92.—Maple injured by burning leaves near the base of the tree.

Paint.

Ordinary house paint, although a crude enough treatment, has sometimes been used by ignorant persons on smooth bark trees, with, of course, resultant injury.

Miscible Oils.

Occasionally commercial oils used for spraying fruit trees for the San José scale cause local injury, and some shade trees have been known to be affected by their use. This is especially true of maples, and it is never safe to use oils of any sort on many smooth bark trees.

Road Oil.

Oils and other materials to keep down the dust in roadbeds are now much in use, and we have observed some injury from this source when the trees were located close to the highway and the buttresses of the roots were exposed. The roots are much more susceptible to injury from various causes than are the trunks, as they are not so well protected by bark, and when oil sprinkled on a roadbed touches some of the exposed roots it kills the tissue. Particles of dust from oiled roads which sometimes alight on the foliage of trees are said to cause injury, but this type of injury is rare with us. Whether the oil ever penetrates deeply enough into the roadbeds to reach the root systems of trees is not as yet known, but if it does it may cause serious injury. Neither are there specific cases of injury to the roots of trees by the dripping of oil and gasoline from automobiles, although if this leakage were sufficient it might reach the roots and cause injury. Not long ago, however, our attention was called to a tree supposed to have been killed by gasoline leakage from a near-by garage.

Creosote.

This material is used extensively on trees for disinfecting cavities, and, mixed with lampblack, for painting gypsy moth egg clusters. It does not appear to penetrate to any great extent when combined with lampblack. We have examined a great many trees to discover injuries from its use with no success, except in the case of linden roots, which had been exposed by regrading, where the underlying tissue was injured. But such instances are rare and the injury purely local in character.

In one case a combination of creosote and naphtha applied to a large number of trees for the destruction of gypsy moth caterpillars appeared to soak into the outer bark, apparently killing the cork cambium, which later resulted in a disintegration of the tissue. Whether these substances did further injury to the tree we were not able to learn.

Coal Tar.

Coal tar is much used for painting wounds and scars caused by pruning, and sometimes injures delicate tissue when first applied. The injury, however, is not serious, as shown by the fact that various saprophytic fungi will develop where the coal tar has been put on. After coal tar has been on for some time it is evidently not injurious, even to delicate tissue.

Salt.

Salt used on sidewalks, in gutters and on trolley lines in winter has been known to cause injury to the root systems of trees. In one instance we noted injury to several small maples growing near a sidewalk and gutter which had been treated heavily with salt. In some cases where salt had been used extensively on trolley tracks, injury to trees was observed. It should not be used near valuable trees.

Other Injurious Factors.

Arsenate of soda, potassium cyanide and other chemicals are extremely poisonous to trees, and when placed in holes bored in the tree the two first named will soon cause death. Since arsenate of soda is often used as a weed killer, it is recommended that care be taken in applying it around the feeding roots of trees.

A quite common opinion among linemen is to the effect that copper spikes driven into trees will kill them, but a small maple so treated by us a few years ago showed no abnormal symptoms.

The foliage of different trees is often injured by spraying with various fungicides and insecticides. It is well known that plum and peach foliage is quite susceptible to this type of injury, and even the leaves of maples and other trees may be injured by arsenate of lead. The extent of the injury depends not only on the nature of the spraying solution or mixture used, but also on the condition of the foliage sprayed. We have observed injury to maples from the use of 12 pounds of arsenate of lead to 100 gallons of water; and Paris green, owing to its present-day uncertain composition, often burns foliage.

Burning insect nests with torches, although a common practice, is a bad one, and invariably causes injury. Serious harm often results from burning leaves and grass around trees, and the roots of forest trees, which are often close to the ground, are sometimes injured by burning the underbrush.

In conclusion it may be said that in any treatment of trees one should always have before him some definite object; he should leave strictly alone the numerous irrational methods constantly being advocated, or apply to them first the measuring stick of common sense.

Banding Substances.

During the past fifteen years a large number of banding substances have been placed on the market, all of which with one or two exceptions have proved injurious to trees. These substances usually contain some oil which affects vegetation injuriously, in some cases even when applied over tarred paper. The injury caused by banding substances varies greatly, the tree often being completely girdled, and again only a local effect is produced; *i.e.*, portions of the tissue here and there will be affected by the material. This results in relieving the tension of the tissue at places, and an abnormal growth of the tissue follows.

"Tanglefoot" appears to be the only substance that does not cause injury when applied directly to the bark, *i.e.*, when tarred or other heavy paper is not used. Many laboratory samples of substances resembling "Tanglefoot" have been made up, but in only one instance have any of these materials resembled "Tanglefoot" in virtually all its properties; at least, among those which have come to our notice. While the injuries from banding substances have been quite pronounced, practically all of the substances causing injury have now been discarded.

An examination made by the writer of many trees treated with the so-called "Tanglefoot" has revealed only one case of girdling, and even in this case we were not able to obtain any clue to the manufacturer of the particular material causing the injury. This substance, although resembling "Tanglefoot," may have been one of its many imitations some of which are known to cause injury. The only other case of injury from "Tanglefoot" was where it had been applied to the trunk at the same place for a number of years. The oil seemed to penetrate the outer bark to some extent, affecting the texture of the bark; but this injury is not serious, so far as we have observed, and can be prevented by changing the location of the band occasionally. We have never noticed any injury from the use of "Tanglefoot" to the cortical tissue or cambium located underneath the bark. Our previous experiments show that the most delicate tissue was not injured when it was applied to various plants. But injury was noticed to smooth bark trees when other banding substances were applied, even on tarred paper. Tarred paper alone is capable of injuring the bark of some trees, and the injury mentioned above may have been caused in this way in some cases.

Effects of Illuminating Gas on Trees.

A much larger number of trees suffer from the effects of escaping illuminating gas in the soil than formerly. The increased death rate from this cause may be accounted for by the fact that gas is now more extensively used, and the larger pipes and different types of connections employed, together with the changes in the methods of laying and calking the joints, also play their part; at least there is much less leakage from small pipes having thread joint connections, which have been in the ground for many years, than from larger pipes calked with oakum and cement or lead. Electric cars, steam rollers, motor trucks and other heavy traffic on highways are often responsible for defective joints and the consequent leakage of gas, especially in newly installed lines. Also, the continual undermining of gas conduits made necessary by the construction of sewer and water lines, as well as the effects of frost in very cold winters, cause leakage; and, finally, the wires, steel rails, etc., carrying electricity are a constant source of danger to gas pipes, as is occasionally proved by cases of electrolysis.

A large amount of the gas manufactured is unaccounted for, often averaging 10 per cent. This loss may be accounted for in part by discrepancies in meter readings, etc., and should not be laid wholly to leakage, and a small percentage of unaccounted-for gas is of slight importance. It should be stated in justice to many of the large gas producers that every effort is usually made to prevent leakage and injury to trees. Some of the most progressive manufacturers spare no expense in constructing and maintaining their lines, although it must be confessed that there is great need for improvement in methods of conveying this dangerous substance. The larger pipes, which are more difficult to keep calked securely, furnish better facilities to patrons; nevertheless the danger from leakage is greater. There are numerous connections in gas mains from which the leakage is slight, perhaps only a few cubic feet a day, while in others it is very great. Even small leaks, if neglected, will injure trees in the course of time, owing to the gradual saturation of the soil with gas.

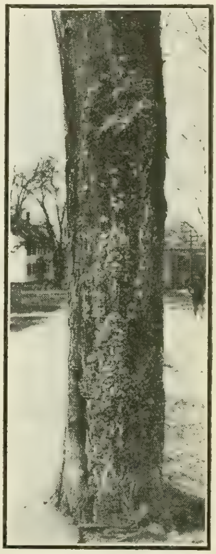

FIG. 93.—Maple tree dying from the effects of illuminating gas, with characteristic fungous (*Polystictus*) growth.

There are several kinds of gas used for lighting and heating, *i.e.*, water gas, coal gas, gasoline gas, acetylene gas and others, but their effects on the plant are quite similar, and they are all very poisonous to vegetation. The poisonous properties are largely confined to the numerous products absorbed in small quantities by the soil moisture, taken up by the roots and translocated through the tissue. The reactions to the substances are not quite the same in different locations nor in different species of trees. Trees poisoned by illuminating gas usually show some characteristic post-mortem symptoms, but the problem of diagnosis is greatly complicated by the fact that many of these symptoms may be found in trees dying from other causes. More or less rapid deterioration and increased brittleness of the wood are quite characteristic symptoms, however.

In summer, the first effects of gas poisoning may be seen in the foliage. The leaves often turn yellow and drop off, while in other cases the leaves will fall when still green, and, again, the leaves will turn a reddish brown and die without falling. The upper part of the tree, being far from the source of water supply, usually shows the effects of defoliation first. These various symptoms occur before there is any evidence of abnormal tissue above ground. But after the water in the soil containing the poisonous gas principles has passed up through the roots and stems, the sapwood, cambium and bark become abnormal. The first symptoms take the form of a characteristic dryness of the cambium and other tissues outside the wood, this being the first indication of the approaching death of the tissues. Later, these tissues — cambium, phloëm and cortex — turn brown, and disintegration follows. The roots, which first absorb the poison, are naturally the first to become abnormal, but later, as absorption and translocation proceed, the poisonous constituents may be detected in the wood at the base of the tree. It not infrequently happens that the tissue here is dead, while that in the trunk a few feet above is alive, but this condition does not endure, the whole tree sooner or later becoming affected. When the underlying tissues die the tissue tensions are destroyed and the bark changes color, gradually growing darker, and its physical properties become greatly changed. Soon various species of fungi, such as *Polystictus*, *Schizophyllum* and others, find a foothold on the bark, and borers and other insects attack the dead tissue. Even bacteria and molds, like *Penicillium*, become active and hasten the process of disintegration. The smaller twigs become dry and brittle, and the ends often break off; the upper limbs usually lose their bark first, but eventually the larger limbs present the same appearance. Disintegration may take place so rapidly that in one and a half to three years the bark disappears and most of the larger branches break off, and soon nothing but a portion of the trunk and a few stubs remains.

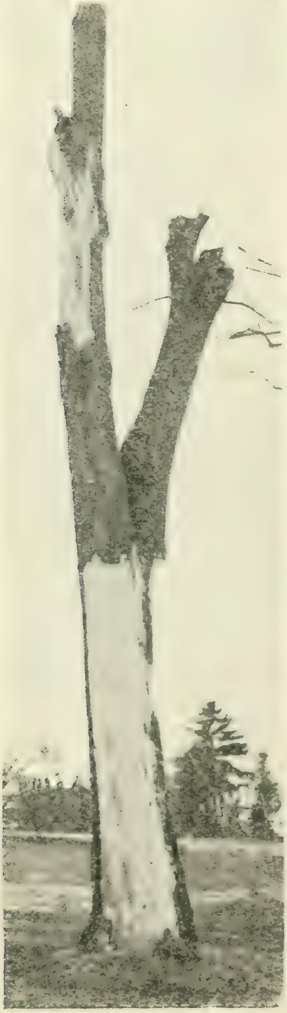
FIG. 94. — Effects of illuminating gas on elm tree one and one-half years after leakage occurred.

It must be understood that many of the symptoms mentioned above may also be found in trees dying from other causes and do not necessarily constitute reliable guides to the detection of gas injury. The tissue furnishes the best symptoms for diagnosis, and the writer, who has for the past twenty years been examining hundreds of trees killed by gas, from the first found it necessary to make a thorough examination of the tissue to warrant any degree of accuracy in the diagnosis. He has

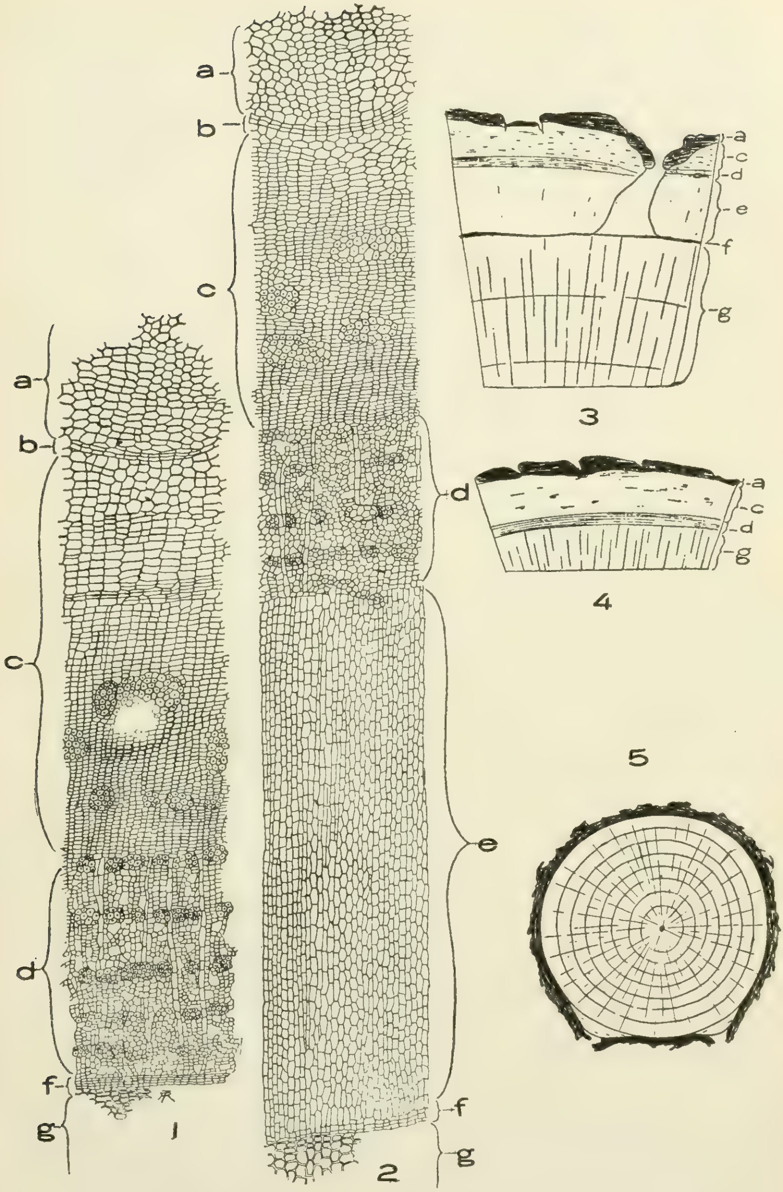

FIG. 95. — Showing cross-section of Carolina poplar (*Populus deltoides* Marsh). 1, Cross-section of normal stem, enlarged; 2, same, showing abnormal growth; 3, naked-eye view of same; 4, section of a normal stem; 5, cross-section of trunk of tree showing the splitting of the bark; *a*, bark; *b*, cork cambium; *c*, cortex; *d*, phloëm; *e*, abnormal parenchyma; *f*, cambium; *g*, wood or xylem.

also taken exhaustive notes on every symptom shown by trees dying from various causes, and from these notes may be had many interesting data on the relative importance of various symptoms. In diagnosing gas injury one must learn to detect either by chemical means or from direct observations and experience the presence of the poisonous constituents of illuminating gas which are absorbed by the roots and circulate to a certain extent through the tissues of the wood.

As already intimated, no two species of trees suffering from gas poisoning present precisely the same symptoms, and there is much difference existing in the same species, the location, season of the year and other factors having an important modifying effect. Trees, for example, when examined in the fall, will show slightly different symptoms from those examined in the spring. This is also true of trees poisoned by gas from different manufacturing plants, which varies considerably. The variation in the chemical constituents of the soil here and there may to a certain extent account for the variations in the reaction of gas on the tissues, but this factor is probably not very important, since these variations in the soil are likely to be found even in a single town supplied with gas from one source, and as a rule the symptoms of trees injured by gas from a single manufacturing plant are alike. Tables giving the results of gas analysis from various corporations, however, show that there is considerable difference in the composition of gas, and that gas from a single manufactory is likely to vary slightly from day to day, not only in the percentages of carbon monoxide and hydrogen, but in the other products.

The odor and color of the tissue should first be examined carefully when diagnosing a gas-injured tree, although it is possible by the use of chemicals to obtain reactions and to detect certain products in the tissue. There are different odors associated with the wood of trees which die from various causes, and it is therefore necessary to become familiar with these before relying too closely on this factor. For instance, molds and other micro-organisms found in the sap of trees dying from various causes often cause decomposition with resultant odors. But there will always be found in trees killed by gas peculiar characteristic odors difficult to describe, and more easily recognized, at least above the ground, after a tree has been dead for a few weeks or months. The odor is more prominent in moist than in dry trees, and can be detected in the tissues of the bark as well as of the wood. Sometimes this odoriferous wood is found deep in the sapwood, and can be recognized in the stumps of trees freshly cut, but in old stumps, where decay has set in, it is not always discernible. In such cases some part of the root system, if dug up, is likely to give a characteristic odor, except when the wood has become too dry and a more or less advanced stage of decay has set in. Even the rate of disintegration and the nature of the decay are often characteristic, and are of some value in diagnosis.

It should be remembered that the odors of different species of trees, even when in normal condition, differ greatly; *i.e.*, the natural odor of the maple is quite different from that of the elm, horse-chestnut or red oak, and their products of decomposition also differ. The accurate diagnosis of trees killed by illuminating gas is highly specialized and technical. Nevertheless the characteristic odors given to the tissue by illuminating gas can be discerned quite accurately by one thoroughly familiar with them. Sometimes these odors are found in all of the tissues of the trunk, but more often they are confined to some special part of the tree or root. They are far more pronounced at the base of the tree, and rarely found in the top. Carolina poplars and willows often display peculiar reactions to gas poisoning. The bark splits open and large masses of soft, parenchymous tissue are formed directly from the cambium layer. When the tree dies this parenchymous[1] tissue decomposes into a mucilaginous mass. (See Fig. 95.) Some species appear to be less often affected by gas poisoning than others. It is a question whether there is much difference in susceptibility, however, as regards species. Trees like the elm and maple, with a large spread of the roots, naturally become poisoned if located near gas leaks, and some trees are adapted to more strenuous conditions and possess a greater capacity for regeneration than others, although they may be as susceptible to poisoning as trees of other species. Coniferous trees possess the greatest resistance to gas poisoning of any species, and in many instances they have been observed surviving in an apparently healthy condition when located dangerously near broken mains, while deciduous trees located much farther away would always succumb. In some cases where conifers have actually been poisoned to quite an extent they have completely recovered. This response may in part be explained by the protection furnished by the coating of micorhiza on the roots of conifers.

We know of no remedies which can be applied to trees already poisoned by gas, since the injury occurs below the surface of the ground, and the effects are seldom noticeable until the poisoning is more or less pronounced. If the leakage of gas could be discovered quickly and the leak repaired, the effects on the roots might be prevented, but this is rarely the case. Illuminating gas in small quantities acts as a stimulus to plants, and there is a certain capacity for adaptation to poisons possessed by them, although limited. By the time the effect appears in the foliage considerable gas has been absorbed by the roots, and since it is impossible to eliminate the gas from the soil, absorption is bound to continue and the tree is doomed. We have known of only a few instances (with the exception of the conifers above noted) in which trees have shown even slight symptoms of gas poisoning and survived for any length of time. In some instances where only one root has been affected, and the poison has not reached the trunk of the tree, amputation of the root may prevent further injury, and is known to have been effective. There are many cases in which trees have not suffered from gas poisoning although located near large leaks, owing to the amputation, during the installation of curbings, etc., of the larger roots which extended over the gas pipes.

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[1] Mass. Agr. Exp. Sta. Rept. 25, 1913, Pt. I., p. 51.

When the soil is charged with gas, digging it up and aerating it is beneficial, and in the case of severe leakage it is well to leave the trench open for a few days, if possible. On the other hand, boring holes in the soil and filling with water or lime is a perfectly useless practice. It is generally believed that if young trees are planted near others which have died from gas poisoning, they will not live, but this is true only in some cases. If the soil is thoroughly saturated with gas, bad results will follow, but if the trees are planted in fresh loam and the old soil aerated, there is little likelihood of the tree dying.

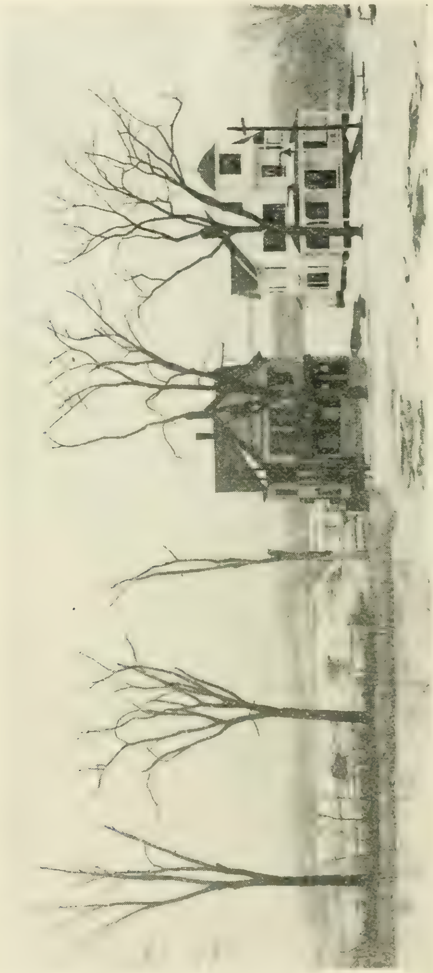

FIG. 96 — Large elms killed by escaping illuminating gas, one and one-half years after leakage occurred.

Gas escaping into the soil from a leak follows the line of least resistance. For this reason, if leakage occurs in the street in front of a house, one can often detect the odor of gas in the cellar, as the gas will follow the exterior of the pipe leading into the cellar, and often escapes into sewers, underground conduits, hydrants, etc. Wells are often badly contaminated even when located some distance away, and in the winter gas leakage becomes a source of danger to near-by greenhouses.

There is considerable difference in the resistance of soils to gas. In gravelly soils we have known gas to travel 2,000 feet when the ground was frozen and escape into the cellar of a house, while in heavier soils it is more likely to be restricted to smaller areas. It requires a considerable amount of gas to kill a large tree, although not so much as it would were it not confined so closely by the soil covers, especially in winter, and by the impenetrable macadam and other styles of modern roadbeds.

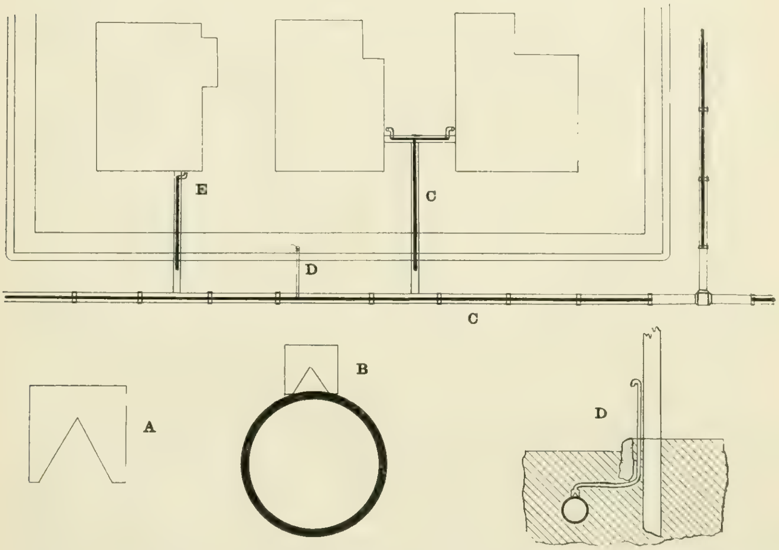

Fig. 97.—Protective arrangement against injury resulting from leakage of illuminating gas. A, cross section of protective conductor; B, adjustment of same to pipe; C, black lines showing method of arrangement of protective device on street and house service; D and E, vents for leakage.

The danger to human life from illuminating gas is too great to be ignored, and even with the present defective systems of distribution it is not only possible but practicable largely to eliminate the dangers from this source to trees as well as to human life by the use of certain devices to prevent the leakage of gas into the soil.

The comparatively recent introduction of joints welded by the acetylene flame may prove superior to the threaded or calked cement and leaded joints in preventing leakage, but this system of laying street mains has not been thoroughly tested out in cold climates. There are also protective arrangements covering the pipes designed to prevent leakage of gas. This protection may be secured by laying a simple device, originated and used by the writer, over the gas main to convey the leaking gas to certain points above the ground, thus preventing contamination of the soil. By using a block system or applying it to sections 100 or 200 feet long, as the case may require, and ventilating each section, a leak may be readily detected and repaired before it has an opportunity to cause any damage. The device made of chemically treated wood and shown in Fig. 97 is suitable for this purpose. It consists of pieces 2 inches square in cross-section and of any desired length. This size may be adapted to any size pipe and secured to it by wires at intervals of 6 to 12 feet (B). Each section, which may be 200 or more feet in length, is vented by means of a pipe running to a pole or tree or any convenient object (D and E), or may be vented directly over the pipe or near the sidewalk or curbing by using an ordinary iron shield provided with vent cap, such as is used for gas shut-offs. This takes care of all the leakage, conveying it into the atmosphere at certain points. If leakage occurs it can be detected by pedestrians and prevented from permeating the soil, where it would be likely to kill trees on the highway. While at present it may not be feasible to equip all pipe lines in this way, all new systems should be protected, and those already laid as fast as possible. This protection should also be extended to house services to prevent asphyxiation to human beings and injury to shrubbery and trees on private property.

Effects of Atmospheric Gases on Vegetation.

The atmosphere of industrial centers is a complex mixture of various substances. Besides the presence of the well-known gaseous constituents found in the atmosphere, — such as oxygen, nitrogen, carbon dioxide and water vapor, — hydrocarbons, solid particles and compounds of carbon, nitrogen, chlorine and sulfur are present in varying quantities. Argon, helium, krypton, neon, xenon and ozone are also found in the atmosphere in small proportions, but so far as is known they cause no detrimental effect to living organisms. Carbon dioxide, which is present in the atmosphere normally ranging from .03 to.04 per cent., is not destructive to living organisms at this dilution. On the other hand, it furnishes the most important source of food for vegetation, and plants will thrive even better with a much higher concentration than that normally existing in the atmosphere. Sulfur, which may be present in the air in several forms, constitutes one of the most injurious agencies to plant life, and sulfurous gases arising from smelters, which often contain other poisonous substances, are frequently detrimental to animal life. There exists some sulfur in most grades of coal, and during the process of combustion sulfur dioxide is given off. This pollutes the air to a certain extent, and if sufficiently abundant will injure plants. When oxygen combines with sulfur dioxide, it forms sulfur trioxide, which in turn forms sulfuric acid with water. Sulfuric acid is very corrosive, attacking and decomposing various building materials, and is more or less injurious to plants and animals. The amount of sulfurous gases in the atmosphere, however, is often quite insignificant, and very exact methods of chemical analysis are required for quantitative determinations. The most exact and refined methods of analysis in use are hardly reliable for amounts less than 1 to 5,000,000 parts of sulfur dioxide. Particles of cement dust, such as may be found near cement manufactories, injure vegetation, as does the soot arising from incomplete combustion of coal. Moreover, dust particles, which may equal 50,000,000 to a cubic inch, form the nucleus of fogs, which in turn imprison various obnoxious gases, thus rendering the dust particles indirectly detrimental to vegetation.

Besides the injury to vegetation resulting from gases associated with smoke, smoke affects vegetation by causing a deposit of soot on the leaves, thus obstructing the light. The soot also clogs the breathing pores or stomata of the leaves, causing asphyxiation. The acids resulting from coal combustion which accompany smoke also affect the soil by producing soil acidity. At Leeds, Eng., a manufacturing city, it is estimated that the daily deposit of soot is about one-half ton, and in the vicinity of other English cities, where much soft coal is burned, the soil has become so impregnated with smoke acids as to be of much less value for agricultural purposes. Soft coal contains more sulfur than hard coal, and combustion is less complete, resulting in more smoke and solid particles, which are conducive to fogs. Fogs hold the sulfurous gases down, and in cities where considerable soft coal is burned such gases affect vegetation more severely.

Soft coal is burned on steam railroads, but the escaping smoke and gases are readily dispersed in the atmosphere. Moreover, the exposure to gases of the vegetation along railroads is of such brief duration that injury to plants is seldom noticeable. Injury to trees is frequently discernible in the vicinity of railroad engine houses, or roundhouses as they are called. Soot is often found deposited on the trunk and foliage of trees in such situations, and the contained gases affect the size and color of the leaves.

Trees in general are affected by atmospheric gases, but some are much more immune than others. The black locust, Ailanthus and peach are especially so, while most conifers and some of the oaks are quite susceptible to injury. Many herbaceous and annual plants, such as morning glory, cosmos, ragweed, etc., are very susceptible to injury from gases. Short-lived trees of rapid growth, such as poplars, willows, box elders, cottonwoods and soft maples, will survive and resist smoke and gases more readily than the oak, elm, hard maple, chestnut and linden. Our native elm appears to be affected most seriously by atmospheric gases, although the nature of the symptoms resulting from constant exposure to atmospheric gases is such that few ever guess their true significance. The pathological effects following exposure to gases indicate troubles of a chronic rather than an acute nature, and the trees gradually lose vigor through a series of years until they finally die. There are many instances in New England, particularly in large industrial centers, where the expectation of life of elm trees is reduced from one-half to one-third the normal, owing to the presence of noxious atmospheric gases, and no amount of soil renovation or tree surgery can correct these conditions.

It is questionable whether injury ever occurs to vegetation from smoke derived from wood, although in one or two instances injury to crops has been surmised. In each case the crops were located near brick kilns.

Lichens are the most sensitive organisms to smoke, although the smoke and gases derived from wood combustion appear not to affect them. These lowly organized plants are invariably absent on trees in cities, and in the thickly inhabited parts of towns where coal is burned, but may be observed in suburban settlements where wood is more used as fuel. These organisms are apparently affected even by the minutest trace of sulfurous gases in the atmosphere.

The greatest injury to vegetation occurs near smelters, where sulfur dioxide and other gases contaminate the atmosphere. In some places vegetation is affected 75 to 100 miles from such establishments. Where sulfur is used for bleaching purposes, and the atmosphere becomes polluted, vegetation is likely to suffer, and many manufacturing establishments which make use of coal-tar products, naphtha, ammonia, carbolic acid, creosote oil, etc., frequently fill the atmosphere with poisonous gases which injure vegetation and animal life. However, the manufacture of sulfuric acid by smeltering companies has done away with much of the injury formerly occurring to vegetation in their vicinity. In the manufacture of sulfuric acid the furnace smoke, which is heavily laden with sulfur dioxide, is used, and in modern equipments most of the sulfur contents are removed. Sulfur dioxide is much heavier than air, and possesses a pungent and characteristic odor. Persons familiar with the odor of sulfur dioxide are comparatively rare who can detect 2 to 1,000,000 parts when present in the atmosphere. Even 3 to 1,000,000 parts is detected by only few, while 4 to 1,000,000 parts is discernible to those of average sensitiveness.

The limitation of injury from sulfur dioxide to the most sensitive plants, or threshold of discoloration as we term it, is according to some experimenters 1 to 1,000,000 parts. This, however, is regarded as the theoretical limit, since it would require many hours to produce visible injury to the most sensitive plant with this concentration, and, as a matter of fact, burning or visible injury probably never occurs in nature with this dilution. Very sensitive plants will show discoloration when subjected to sulfur dioxide from 3 to 4 parts to 1,000,000 if they are exposed to this concentration for a number of hours. Or, in other words, to produce burning a concentration would have to exist in the atmosphere for some hours, even when present in sufficient quantity to be discernible to the sense of smell. Burning in general from various gases presents different appearances, and the same gas will produce entirely different pathological symptoms even in the same species. Burning from gases in general is affected by light, soil and air moisture, and the age of the foliage constitutes a factor, as probably does the condition of the stomata or breathing pores of the leaves, which vary in number from 800 to 170,000 per square inch of leaf surface.

Some recent European experiments show that burning from gases is intimately associated with sunlight, a fact long recognized by American gardeners in connection with the fumigation of greenhouses. Fogs and mists are conducive to burning. As is well known, they have a tendency to drive gases downwards, imprisoning them, as it were, and preventing their diffusion. Burning even with the same concentration of gas is more severe in moist than in dry air. Southern exposures are the most favorable to burning from gas, as are the exposed tops of trees, where the light conditions are more intense, and it has been demonstrated that burning is associated with the assimilative activity of the leaf, which is at its maximum during bright sunlight. Hence, a plant in sunlight will show discoloration or burning at a much less degree of concentration of the gas than during cloudiness or darkness, and the proportions of sulfur dioxide in the atmosphere must be considerably greater to produce the same effects under poor light conditions than during sunlight.

As the stomata or breathing pores are open during bright sunlight and closed during dull days and darkness, these organs would appear to have some influence as regards burning. However, experiments have shown that the stomata or breathing pores of the leaves, at least in some cases, close immediately when exposed to various gases, and in this way they may prevent severe injury to a certain extent. The age of the leaf is very important as regards susceptibility to burning, the younger leaves not being so susceptible to burning as the older ones. This is shown by injury from illuminating gas in greenhouses. This gas affects the older foliage, while the younger leaves remain normal or unaffected with small dosages. This may be explained in two ways, *i.e.*, that the stomata of the older leaves which are injured are more or less inactive, whereas on the younger ones they are more active. Moreover, the assimilative processes more nearly approach their maximum condition in the well-developed or older leaves than in the younger ones; or, in other words, carbon assimilation is undoubtedly more active during June and July than during April and May in some species, and as burning is associated with the assimilative activity of the foliage, burning may naturally be expected to occur more severely to older leaves than younger ones. The probability of the inactivity of the leaf stomata constituting a factor in susceptibility to burning from gases is borne out by the fact that some species which possess thick and tough leaves appear to be the most susceptible to burning, and the inability on the part of the stomata to respond to external influences may be an important factor underlying injury from gases. The condition of the atmosphere is often extremely variable even in the same locations, and any gas would be variable in its concentration, hence one part of sulfur dioxide per million might be present for a few moments at any particular point, while a few moments later only slight traces would be found.

The preparation of asphalt and tar on streets lined with shade trees sometimes results in burning of the foliage; and this is also true of steam rollers when employed for road work.

Sewer gas has often been suspected of injuring shade trees. The constituents of this gas are, however, extremely variable. Some of them are toxic, and in sufficient quantities are capable of injuring vegetation. As a matter of fact, however, injury to plants from sewer gas seldom occurs; on the contrary, sewers and cesspools furnish one of the best environments for root growth. Even when the poisonous gases of the sewers reach rather high percentages they are seldom produced in large enough quantities to do harm, and soon become diffused in the atmosphere.

In summarizing the effects of smoke on vegetation the following factors should be considered: —

Smoke is the product of combustion diffused in the air, and may be either visible or invisible, affecting vegetation in the following ways: —

By retarding growth and development of plants in consequence of the presence in the atmosphere of noxious gases, acids, etc.

By causing a direct burning of the foliage resulting from the gases present.

By causing asphyxiation through the deposition of soot on the foliage.

By reducing the light intensity and thereby affecting photosynthesis or carbon assimilation.

By constituting an important factor in the formation of fogs, which increase the susceptibility of plants to injury from gases.

By combining with certain soil constituents to form an acid soil, thereby affecting the roots of plants.

Smoke affects plants both directly and indirectly, although the effects are often slow in asserting themselves.

The direct effects of smoke arise from the products of combustion, such as soot and sulfurous gases, which affect the foliage and young shoots, also the soil, and, consequently, the roots of plants.

The indirect effects of smoke follow as a result of fogs, which are due to the solid particles present in the smoke and which also interfere with the normal light conditions, thereby affecting photosynthesis or carbon assimilation.

The factors involved in burning from gases may be classified as follows: —

1. Inherent susceptibility to burning, which is determined by the anatomical and physiological characteristics of the organism.

2. Susceptibility of a periodic nature, which is associated with the activity of some particular life cycle function.

3. Susceptibility associated with meteorological conditions or agencies.

ELECTRICAL INJURIES.

The increase in electric railroads, electric lighting systems and telephone lines, whose wires are usually located near the tree belts of our cities and towns, has made necessary a lamentable amount of disfiguring pruning. When strung too close to trees, wires also often cause serious injury by burning, sometimes mechanical injury is done, and lightning discharges will cause harm when guy wires are attached to trees.

Both the alternating and direct currents are used. They produce different physiological effects on plant life, the alternating current apparently being less injurious than the direct; and when either is used at a certain amperage it acts as a stimulus to the plant, and growth and development are accelerated.

There are minimum, optimum and maximum currents affecting plants. The minimum represents that strength of current which just perceptibly acts as a stimulus, and is very insignificant. The optimum is that producing the greatest stimulus — about .2 milliampere — and the maximum, that causing death. The maximum current necessary to cause death is very variable. The direct current has a less stimulating effect than the alternating, and on account of its electrolyzing effect is capable of causing more injury to vegetable life than the alternating current.

Most of the injury to trees from trolley or electric light currents is local, *i.e.*, the injury takes place at or near the point of contact of the wire with the tree. This injury is done in wet weather when the tree is covered with a film of water, which provides favorable conditions for leakage, the current traversing the film of water on the tree to the ground. The result of contact of a wire with a limb under these conditions is a grounding of the current and burning of the limb, due to "arcing." The vital layer and wood become injured at the point of contact, resulting in an ugly scar and sometimes the destruction of the limb or leader. In a large number of tests made by the aid of sensitive instruments with guy wire and other connections of wires to trees we have never found any leakage during fair weather or when the surface of the tree is dry. Since the amount of current that can be passed through a tree depends upon the resistance and electromotive force, we shall consider this resistance.

As might be expected, there is considerable difference in the electrical resistance of various trees as well as of the different tissues found in trees. The heartwood, sapwood, cambium, bark and sieve tubes possess quite different properties and functions, and their electrical resistance would naturally vary to a large extent. The living cells containing protoplasm, such as are found in the cambium, present the least resistance, as shown by various observations on lightning discharges. The minute burned channel caused by comparatively insignificant lightning discharges follows down the cambium, indicating that this is the line of least resistance. Moreover, by driving electrodes into a tree to different depths and measuring the resistance it can be shown that the least resistance occurs in the region of the cambium.

The electrical resistance may average throughout the year about 25,000 ohms in 10 feet of the trunk of a large maple tree, but in cold weather it often exceeds 100,000 ohms. The lowest resistance in all cases corresponds to periods of high temperatures, and the highest to periods of the lowest temperature. The difference shown by the various sides of the tree is also related to temperature. The resistance of the sapwood is very much greater, and probably that of the heartwood is even higher than that of the sapwood.

In determining the electrical resistance it is necessary to know the path or course of the current, and the only manner in which the resistance of different tissues can be determined accurately is by isolating the tissues. By girdling a tree and scraping the trunk down to the solid wood we can get the resistance of the wood. Mr. G. H. Chapman[1] found the resistance of a freshly cut rock maple stem, 1½ inches in diameter, to be 70,000 ohms with the bark on, but 150,000 ohms when the bark was removed. The electrodes were 1 foot apart. Next to the cambium the phloëm has the least resistance, followed by the sapwood. The outer bark appears to offer the most resistance, but when wet the resistance may be decreased, owing to the less resistant film of moisture on the bark. The resistance obtained from an elm tree in summer, with the electrodes 10 feet apart and in contact with the cambium, was 10,698 ohms, whereas when the electrodes were inserted into the middle of the cortex or phloëm we obtained 11,300 ohms' resistance. When driven one-quarter inch into the wood, and some of the exterior tissues surrounding the electrodes removed, the resistance was 98,700 ohms. The outer bark gave 198,800 ohms' resistance, but when the electrodes were inserted slightly deeper into the bark we obtained 109,900 ohms. It should be pointed out, however, that the data given here do not represent the actual resistances of the various tissues, but they indicate that there exist very material differences in the electrical resistance of the tissues in trees. The resistance obtained for the cambium, however, may be taken as fairly representative, as shown by the use of other methods, such as the employment of relatively high potentials and current measurements.

The resistance given by small tree trunks and woody stems, even for small distances, is quite large. About 4 feet of a young pear tree, including the root system, with a maximum diameter of stem equal to 1 inch, gave a resistance of about 300,000 ohms; and the resistance given by a tobacco plant, in which the distance between the electrodes was only 14 inches, was much higher (110,000 to 165,000 ohms) than that shown by trees at corresponding temperatures.

The water and various salts in the living plant undoubtedly play a rôle in resistance, and it might be expected that the various plastic substances would influence it also.

The cambium ring is very insignificant in size, and even on a large tree the total area is small. In all probability it is the protoplasm itself which offers the least resistance to the transmission of an electric current; and even if there were no continuity it would be necessary for the current to pass through a great many cell walls even for comparatively short distances on the trunk. In case the protoplasm was continuous or there existed continuity, the strands would be so very small that they would undoubtedly offer high resistance, due to their attenuation. Whatever conditions prevail, trees show relatively high electrical resistances, a feature which is no doubt of some biological importance. The high resistance of trees, moreover, is undoubtedly a protection in case of lightning strokes, since often the heat developed is enough to do only slight injury. On the other hand, if trees possessed tissue with relatively small electrical resistance, they would be more seriously affected by currents from high-tension wires. The electrical resistance of trees is so high that it is doubtful whether injury ever occurs to them from contact with low or even high-tension wires, except that produced by grounding when the bark is moist. Any escaping current from transmission lines that can be transmitted even through the least resistant tissue is likely to be insignificant.

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[1] Mass. Agr. Exp. Sta. Rept. 24, Pt. I., 1912; also Bulletins 91 and 156.

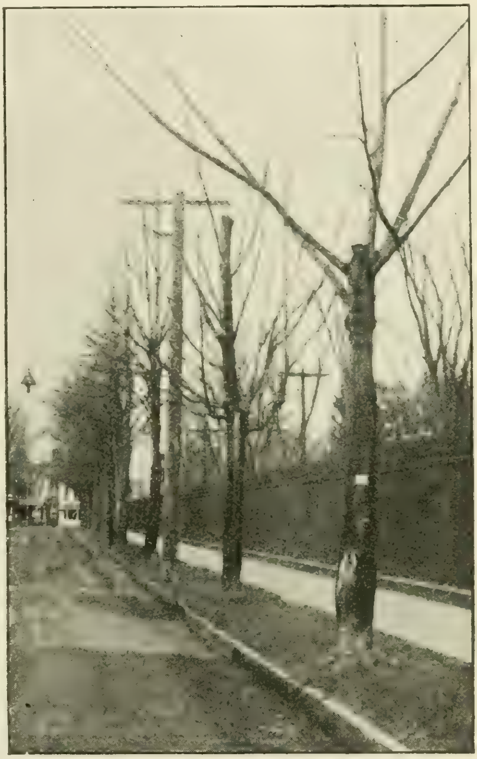

FIG. 98. — Showing disfigurement of trees caused by high-tension alternating current wires.

Effects of Alternating Currents.

The alternating current systems employed for lighting purposes vary greatly in their potential. Cases of burning from alternating currents are more numerous than those from direct currents because trees are brought into more frequent contact with the wires, and, owing to the higher potential, more leakage is likely to occur. The high and low voltage lines may vary from 100 to 100,000 volts. The high-tension systems are invariably constructed across country, and are naturally not brought into very close proximity to shade trees. No injury to trees whatever occurs from the low voltage (110-volt) lines, but the lines of higher potential found on streets constitute a source of danger to trees. The higher the electrical potential the more dangerous the wires become to trees, for, owing to the lessened effectiveness of the ordinary insulation, more leakage occurs and consequently greater opportunity for burning.

The effects of alternating currents on trees are local, producing injury only near the point of contact with the wire. Such contact results in death of that part of the tree, and if it is a leader or large limb it usually has to be sacrificed. In no case, to our knowledge, has an alternating current caused the death of a tree, although it may burn or disfigure the tree so badly that it amounts to practically the same thing. It is doubtful whether the current from a fairly high potential wire would kill a large tree under any circumstances. It is different in the case of small plants, as has been frequently demonstrated in the laboratory, although the current must produce heat enough to kill the protoplasm. The close relationship between the maximum temperature required to kill a plant and that induced by electrical current indicates that the collapse of the plant tissue in such cases is probably due to the heat rather than to any specific electrical shock. It is possible to pass the same current through larger plants where heat is not generated without causing any collapse of the tissue. The ordinary house circuit wires are perfectly harmless to trees, and it seems strange that a judge could render a verdict to the effect that an ordinary insulated 110-volt house circuit was responsible for the death of a tree whose terminal branches were located 3 feet from it. There is only one court record of which we know where such a judgment has been given.

Very high-tension line wires are not provided with insulation and are known to affect the atmosphere surrounding them to a considerable extent. Any increase in the electrical potential of the atmosphere if not too high would favorably affect vegetation in general.[1]

General Effects of Direct Currents.

Most of the direct currents affecting trees are those used for operating electric railroads. Trolley feeders may be at 500 to 550 volts. Ordinarily the burning from direct currents is similar to that produced by the alternating current in being largely local or confined mainly to the point of contact with the wires. The feed wires cause no burning except when the tree is moist, in which case grounding takes place.

The strength of current which will kill one plant will produce not the slightest effect on another; in other words, the maximum current for each individual varies materially. Small, tender plants possess a maximum much below that of woody plants. A young, succulent tomato plant, one-eighth inch in diameter and 5 inches high, was instantly killed when treated with a current of 20 milliamperes, and currents of 2 and 3 milliamperes of thirty to sixty seconds' duration accomplished the same result. In all the tomato plants, considerable heat was developed, and their death was caused by the generation of heat developed by the current. The electrodes in these tests were about one-half inch apart. If the electrodes had been farther apart, no perceptible effect would have been observed.

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[1] There is evidently much difference in plants in this respect. A crop of radishes showed a gain of 57 per cent. when subjected to an average atmospheric potential of 167 volts, whereas an electrical potential equal to 500 or 1,000 volts is beyond the stimulation zone for some plants (16th Ann. Rept. Mass. Agr. Exp. Sta. (Hatch), 1904, p. 31).

When trees with a more or less thick bark are drenched with rain the conditions are quite different. A large maple tree which was in circuit with a feed wire (500 volts) and rail of an electric road when dry gave a current equal to 70 milliamperes (one-fourteenth ampere) with the electrodes placed vertically 1 foot apart. These connections were left on the tree for several months. The observations were made on dry days and no appreciable amount of heat developed with this current. During periods of wet weather considerable heat always developed, especially at the positive electrode, but not enough to melt the soft solder which connected the wires with the electrodes.

Examination of the tree ten months later showed that a portion of the tissues near the electrodes had been killed. After removing the dead bark an oval space 6 by 11 inches was found to be dead about the positive electrode and a space about 1½ by 3 inches near the negative electrode. The burned area about the positive electrode was about 95 per cent. greater than that occurring about the negative electrode; in each case it extended about twice as far above and below the point of contact as out to the sides of the electrodes, thus showing a tendency of the current to spread laterally as well as vertically, but more largely vertically. The immediate area around the electrodes was more affected than that farther remote. There was an area of tissue about 5 inches long between the large and small oval burning that was uninjured, showing that burning was confined about the electrodes. The current traversing the film of water on the bark between the electrodes was not sufficient to destroy the tissues at that point.

If a milliammeter had been placed in the circuit when the tree was wet a greatly increased current would have been detected, since the current in this case traversed the less resistant film of moisture on the bark. But the electrical resistance of the vital layer under such conditions would remain practically the same as when the tree was dry, or it would show only such variation as might be induced by an increase in temperature. The burning and injury in this case resulted from the heating of the film of moisture, which became so intensely heated that the vital tissue was destroyed, especially near the point of insertion of the electrodes. The more the film became heated the greater was the lessening of the resistance and increase of the current.

Practically all of the burning of trees from either alternating or direct currents occurs in this way, since the high electrical resistance characteristic of trees does not permit injurious currents to pass through their tissues.

Death of Trees from Direct Current.

Instances are known in which large trees have been killed by direct currents used in operating electric railroads. Attention was first called to these cases in Bulletin No. 91, issued by this station, and since the publication of this bulletin other cases have been observed. In all of these cases the escaping current had burned and girdled the trunks for a distance of from 5 to 10 feet from the base; the point of contact of the feed wire with the limb 18 or 20 feet above showing little or none of the characteristic local burning effects usually observed in ordinary cases of grounding. In fact, the difference between the burning from direct currents in these cases and that from ordinary cases of electrical injury may be seen at a glance. On electric railroad systems the so-called positive current generally traverses the overhead feed wire, where the injury (burning) takes place. It does not differ materially from that produced by low-tension alternating current wires. In all cases of death from direct-current electricity that have come to our notice, however, the rail was positive and the overhead wire was negative, constituting what is called a "reversed polarity." How common this practice is we cannot say, but apparently it has been employed intentionally at times to prevent electrolysis as well as unintentionally by various companies, and is responsible in a few instances for the death of shade trees near electric railroads. There is much greater opportunity for extensive burning in the case of reversed polarity than in the regular systems employed. The moisture conditions of the soil and bark are such as to reduce the resistance, and in consequence the film of water and the water-soaked bark

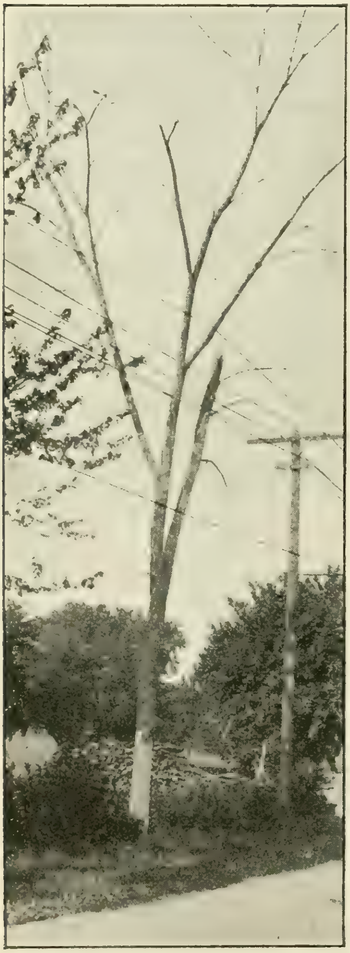

FIG. 99. — Showing elm tree killed by direct current (reversed polarity) from electric railway system. Note effects of burning at the base of the tree.

become intensely heated, destroying the living tissues and girdling the tree to a considerable distance. The part of the trunk towards the rail is almost invariably the most severely affected. With reversed polarity, as already pointed out, the injury is confined mainly to the base of the trunk, where the destruction of tissues causes great damage. Such damage does not occur when a positive overhead feed wire comes into contact with limbs. The entire area between the base of the tree and the overhead wire is not, as a rule, affected, although the extent of injury may vary somewhat. On the elm shown in Fig. 99 the burning was caused by a reversed system, and there was only slight injury at the point of contact with the overhead wire, while at the base about 6 or 7 feet of the tree were affected. This injury takes place when the soil and the bark of the tree are moist, and may occur during a single period of excessive moisture, or intermittently. In some instances trees show serious effects a short time after the current has been reversed, when the bark will become loose and later fall off. The writer has observed both elms and maples — some of them 2 feet or more in diameter — which have been killed in this way. In some cases the trees were not more than 3 feet from the rails, while in others the distance was considerably greater.

In one city, 51 trees were reported killed or so badly injured as to be of no value, 67 had large limbs removed, and many more were saved by removing limbs likely to come into contact with wires. Some of the injury took place on streets having trolley wires but no electric railways, and it is surmised that the ground connections were made through several pipe lines located near the trees, which led very close to the electric railway. According to Mr. G. A. Cromie,[1] who had these under observation, the injured trees were in some cases located from 200 to 1,000 feet from the track. The effects on the trees were noted shortly after the street railway had changed its system, *i.e.*, using the rail to carry the positive and the overhead wire the negative or return current. The trees in contact with the overhead wires became electrically charged, and when wet it was impossible for linemen to work on them. Under these conditions the insulation was much less efficient, and even wooden sleeves imbedded in coal tar and rubber proved of small use in preventing leakage. A large percentage showed a characteristic burning at the base, and the bark was burned off in some instances to quite an extent. One limb that had been in contact with the negative feed wire was found dead, but the tissue at the base of the trunk was normal. Dr. J. W. Toumey, director of the Yale Forestry School, who examined many of these trees, found a disintegration of the wire where it came into contact with the limbs, apparently due to electrolytic action, and chemical analysis showed the presence of copper and zinc in the tissues of the wood that had been in contact with the negative or overhead wire. Dr. Toumey believes that in such cases the disintegration of the copper wire and the absorption of the copper by the tissue were responsible for the death of the limbs. If true, this entirely new state of affairs would indicate that the electrical injury from direct currents arises not only from heat but also from the electrical disintegration of metals, which may poison the tissues. These observations demonstrate that we have a variety of conditions to deal with in considering the effect of direct-current electricity on trees, and these phenomena may be summarized as follows: —

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[1] G. A. Cromie, "Scientific American" supplement, No. 1985, p. 40, Jan. 17, 1914.

Burning and injury to plant tissue are much more prominent at points with a positive potential[1] *than at points with a negative potential.*

When the rail is at a positive potential and the overhead wire which touches some part of the tree is negative, and the bark and soil are saturated with moisture, a circuit is formed by means of this surface moisture.

The moisture conditions and the electrical resistance, etc., at the base of the tree are different from those above; therefore, a larger area of tissue is affected by the positively charged rail.

As the bark becomes heated through the film of water, the electrical resistance is reduced and the current increased to such an extent that the vital layer is destroyed.

The actual current passing through the inner tissues must necessarily be insignificant, and when there is a film of water on the bark, probably no current passes through the cambium; furthermore, the moist soil between the rail and the trunk of the tree becomes a better conductor for the current than the roots. The actual injury, therefore, is done by the current traversing the film of water rather than any of the inner tissues. The maximum heat and the areas most affected are near the base of the trunk.

In regard to the possibility of injury to large trees by direct currents passing directly through them, experiments show that what holds true for alternating currents is true also to a great extent of direct currents. However, it would require a voltage much higher than that furnished by most electrical railways at the present time.

It might be possible for direct currents to affect trees without causing any perceptible burning. If, for example, a tree were subjected to a sufficient strength of current, there might occur a disintegration of the cell contents, causing the tissues to become abnormal and finally to die, but the electrical resistance of trees is so great that a quite high potential would be necessary. If the potential of the electric railway systems were greatly increased it is possible that some injury might result to trees even under ordinary conditions.

Probably the amount of ground leakage occurring through imperfect rail connections would not cause any perceptible injury to trees; nor is there any direct evidence that lightning arresters when placed near trees cause any injury by discharges. However, the guy wires used by electric systems are a source of danger from lightning, and we have observed cases where large limbs have been destroyed and the trunks of the trees badly lacerated by electrical discharges from these wires.

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[1] Positive electro-static charges have a more stimulating effect on plants than negative charges, and retardation of growth and injury to the cells are more pronounced. The phenomena associated with the positive and negative galvanotropic bendings of roots may be explained in this way (24th Ann. Rept. Mass. Agr. Exp. Sta., Pt. I., p. 144, 1912).

On the whole, the cases of death to trees from electricity are by no means so numerous as is generally believed. Because a large number of trees near electric roads, etc., often look sickly it must not be concluded that electricity is always the cause. In cities and towns, where most of these unhealthy specimens are found, there are innumerable destructive factors for trees to contend with. It is quite essential in diagnosis work, therefore, that all of these factors be taken into consideration before a definite opinion in regard to the cause of any abnormal condition is formed.

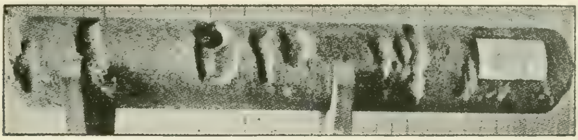

Fig. 100.—Showing electrolysis of gas pipes. (After A. A. Knudson, "Corrosion of Metals by Electrolysis.")

Electrolysis.

Direct current electricity is frequently responsible for electrolysis of gas and water mains, and lead coverings of underground telegraph circuits are often affected. The trouble is often so serious that the iron gas and water pipes become corroded and eaten with holes in a few weeks or months, causing leakage. When gas mains are affected by electrolysis, the gas escapes and permeates the soil, so that electricity sometimes becomes a primary and gas a secondary factor in the death of trees.

The phenomena associated with electrolysis are often complex and difficult to do away with entirely, according to expert electricians, but much of the trouble can be eliminated by proper bonding of the rails of electric roads and the grounding of different systems.

Electrolysis is more common in wet than in dry soils. Cases are on record where severe electrolysis has taken place 700 or more feet from the source of the leakage. It more often becomes troublesome in cities where numerous railways and public-service corporations of all kinds make use of the streets. We have observed cases where plants have been stimulated and their growth increased by escaping electricity in the soil.

Lightning.

The common effects of lightning strokes on trees are so well known that it is not necessary to dwell upon them here; but lightning does not always strike a tree in the same way, and the peculiar effects sometimes produced are often interesting. Very powerful discharges of lightning act somewhat like an avalanche, causing a severe shattering of the tissue, while less powerful discharges may remove a strip of wood only a few inches wide and 1 or 2 inches thick. Lightning often takes a spiral course, following the grain of the wood, which is sometimes very irregular. Even when strips of wood 4 or 5 inches wide and 2 or 3 inches thick are removed, in which case the electrical energy is enormous, the path of the discharge is shown only by a dark-colored streak 2 or 3 millimeters wide.

Sometimes trees are killed outright by lightning without being shattered or displaying any other of the common effects. In such cases the discharge is apparently dispersed so as to cause no visible mechanical injury to the tree, but the girdling of a large or small area of the living zone or cambium layer of the trunk would be sufficient to cause its death. This might follow as a result of an earth discharge either destroying the vital tissue directly or by a dissipation of heat over a surface film of moisture. In some instances the leaves wilt immediately and die, indicating injury from heat. However, in a very large number of instances neither death nor mechanical injury of any importance takes place. Hundreds of trees are annually struck by lightning that never show any effects except to those capable of interpreting the small narrow ridges which later make their appearance on the trunk. In such cases the lightning discharge follows the line of least resistance, — the cambium zone, — burning a small channel usually about 1 millimeter in diameter. The tissues surrounding the channel are apparently not injured, but the annular rings which are later formed outside the burned channel are much broader, resulting in the formation of a ridge on the bark.

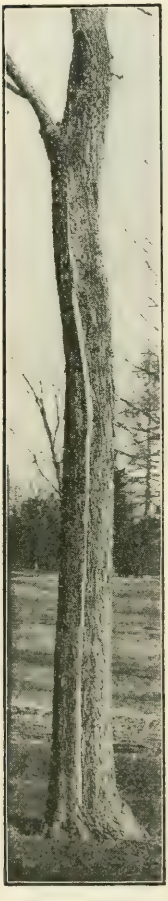

FIG. 101. — Showing ridge on elm tree caused by feeble lightning discharge.

Earth Discharges. — There are many cases of lightning that are apparently earth discharges. Their effect on the tree is quite characteristic and not at all similar to the ordinary forms of lightning strokes. Our attention was called several years ago to some shade trees to which lightning had apparently caused some injury. These trees were maples 5 to 18 inches in diameter, growing in soil composed mainly of gravel containing oxide of iron, and underneath this a stratum of quicksand. A considerable number of the trees showed the effects of repeated earth discharges, in some cases becoming so disfigured that they had to be replaced for the third time. These discharges occur during thunderstorms, and those who have observed them for many years relate that they give rise to a dull, characteristic report resembling that caused by throwing a wet cloth on a hard surface. The whole tree is not affected as a rule, as the lightning stroke seldom follows up the main trunk, but discharges at the points of several branches. As a rule, however, one side of the trunk and one or more of the limbs on that side are affected and the symmetry of the tree destroyed. The first indication of the discharge is shown by the immediate wilting and subsequent death of the leaves of the affected limbs, which also die later. In the course of time cracks similar to those caused by frost, and later ridges due to healing, will be seen on the trunk, showing the path of the discharge, and occasionally, when the injury is considerable, the bark near the affected part of the tree falls off. The limbs, however, are not always killed, frequently splitting, and a cracking of the wood for some depth is now and then observed on the trunk and limbs along the path of discharge.

Whether the chemical composition of the soil has any particular bearing on earth discharges is not positively known. It is known, however, that there frequently exist great differences in the electrical potential between the earth and air during thunderstorms, and that the electrical conditions of the atmosphere and earth may change instantly from negative to positive. Some observations made in our laboratory with a Thomson self-recording quadrant electrometer show that the electrical potential of the atmosphere, at a distance of 30 feet from the ground, may vary, often in a brief period, from a few volts to 300 or more. It is also known that trees occasionally discharge sparks at their apices, showing that insignificant earth discharges occur through trees; and when the soil in which potted plants are growing is charged electrostatically, small sparks are thrown off from the leaves. Earth discharges through trees, whether strong or weak, appear to be similar in nature, and may be associated

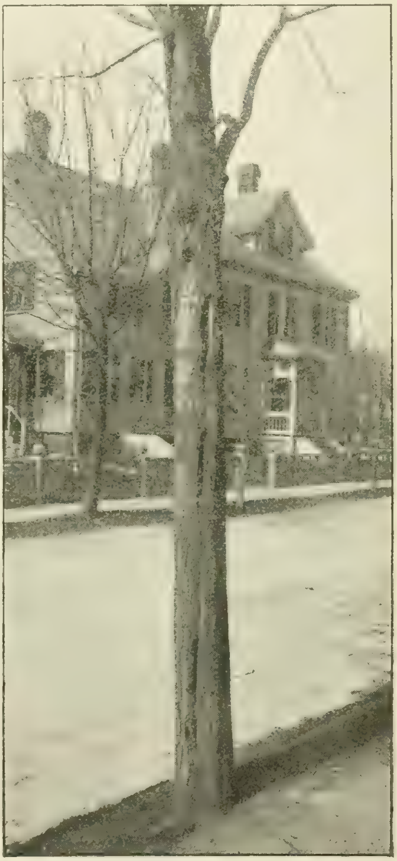

FIG. 102. — Maple showing effects of earth discharges (lightning), causing splitting of the trunk and death of limbs.

with changes in the potential of the earth and atmosphere. The high electrical resistance shown by plants in general, as already stated, serves as a great protection against death from lightning and electric currents.

Susceptibility of Different Trees to Lightning Stroke. — There has always been much difference of opinion in regard to the susceptibility and non-susceptibility of various trees to lightning, and the data of the subject gathered from this and that source are altogether too meager to admit of reliable conclusions; but it is known that the location of the tree, nature of the soil, elevation, etc., are of great importance in determining susceptibility to lightning.

It has already been pointed out that electrical resistance is influenced by temperature, and the percentage of moisture in the tissues is also an important factor. During thundershowers, trees become more or less drenched with rain, and, according to Stahl,[1] the more thoroughly wet the tree is the less susceptible it becomes to lightning stroke. He bases his observations on the fact that smooth-bark trees, like the beech and others, which are considered more immune to lightning, become thoroughly wet during storms, while the oak and other rough-bark trees do not. Stahl's idea, therefore, is that smooth-bark trees possess a better water-conducting surface and have a tendency to equalize the electrical tension existing between the atmosphere and the ground, so that they are rendered less susceptible to lightning. His deductions were based upon experiments with electrical discharges made with the bark of different species of trees containing various percentages of moisture. He further observed that vertical limbs were more likely to become drenched than horizontal, and that the lenticels and stomata play a rôle in the equalization of the difference in electrical potential existing between the tissues and the atmosphere. There appears to be no difference in the electrical potential, at corresponding heights, under deciduous trees and in the open air when there is no foliage, while the electrical potential will average 40 per cent. less under the trees than in the open air when the foliage is developed.

The potential of the air is usually negative, although occasionally changing to positive. In the case of coniferous trees, however, like the Norway spruce,[2] we found that the potential under the foliage was invariably positive or similar to that of the earth, which may be explained on the theory that conifers are constantly discharging positive electricity to such an extent that the air surrounding them becomes charged similar to the earth. To what extent the film of water on the bark is capable of equalizing the difference in electrical potential in the air surrounding the trees, as well as in the ground and in the tissues themselves, has not been wholly determined, but we had difficulty in obtaining potential readings under the foliage of elms in wet weather in our experiments covering two summers. This may in part be explained by the improper installation of our collector. It is not unlikely that the film of water on the bark of trees during such periods would have a tendency to affect materially the potential of the surrounding air, as Stahl has pointed out, and possibly to equalize the electrical tension. The subject should have further investigation, but we believe that it is possible to protect trees from injury by lightning, whether they be atmospheric or earth discharges.

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[1] Stahl, E. Die Blitzgefährdung der verschiedenen Baumarten, Jena, G. Fisher, 1912.

[2] Mass. (Hatch) Agr. Exp. Sta. Rept., 1905, p. 14.

Injuries to Trees from Arc Lamps.

Damage to trees from artificial light rarely occurs. We know of only one instance where any definite injury has occurred to trees from the use of the arc light. Mr. William G. Keith, gas and electric light commissioner of Chicago, Ill., has reported a case where the electric lights caused damage to adjacent trees located on certain streets in Chicago. The trees injured were in all cases young Carolina poplars. The particular lamps causing the trouble were known as the G. E. Company, type W, 10 ampere, 465 watt, 1,000 candle-power, series flame arc lamps, and were operated on the same circuits. These lamps were in operation nearly a year. Shortly after their installation damage occurred to the poplars adjacent to the lamps. The damage to the trees in all cases was confined to that side near the source of light, the trees being stripped of leaves and some of the branches apparently killed. The injury to the branches was such that they became infested with borers. As the injury to the trees seemed to be persistent where this type of lamp was employed and not noticeable where other types of lamps were used, — such as the direct-current open arc lamp and the 300-watt 600-candle-power gas-filled incandescent lamp, — the system was changed to the latter type, and the trees became normal, throwing out new twigs and leaves.

At first it was thought that the heat generated by the lamps was responsible for the damage to the trees, but the heat generated from the gas-filled lamps was equal to or greater than that from the other types; hence it appeared that the damage did not result from the heat. Finally it was demonstrated that the trouble was caused by the practice of emptying the contents of the globes, consisting of such products of combustion as fluorides and possibly other injurious salts which accumulate in them. The trees were located very close to the lamps and somewhat below them; hence in emptying the globes the poisonous products would fall on the foliage. As already stated, the injury in all cases occurred on that portion of the tree adjacent to the lamp, the other or remote portions being unaffected.

This is apparently the first authentic case at least of noticeable injury to street trees from electric lamps, and the theory of Commissioner Keith relative to the specific cause of the injury to the foliage — namely, it being due to the deposition of the products of combustion from the carbon on the foliage — appears to be a most rational one. It should be pointed out, however, that there are other ways in which injury of a similar nature might occur to trees from electric lights, and as innovations in street lighting systems are frequent, attention should be given to this subject by those having the welfare of trees in their charge.

It would, of course, be possible for injury to be produced directly to the foliage of trees in close proximity to lamps resulting from the intense heat produced by the electric current setting free poisonous gases from the heated carbons used for lighting purposes, the carbons in such instances being composed of or containing chemical substances which when volatilized by intense heat and diffused in the atmosphere would be toxic to plants.

Moreover, it is possible for light itself to affect vegetation detrimentally. It is well known that artificial lights differ from sunlight very materially, and in proportion as they are characterized by rays of high refrangibility they produce abnormal conditions on vegetation. However, the injurious effects to plants resulting from various artificial lights can be and are eliminated to a large extent by the use of globes and glass screens. We have never observed, however, any detrimental effects upon shade trees from any lighting system which could be attributed to any peculiarity in the nature of the light itself.

The carbons in the older type of arc lamps which have been extensively used are supposed to be pure, while those used in the flame arc contain certain admixtures, such as fluorides. The older type of arc lamps provided with pure carbons were apparently harmless to street trees and to vegetation in general when the light was properly screened through glass, although more or less delicate, rapid-growing plants became abnormal when subject to the naked arc.

Apparently the flame arc lamps have not as yet been extensively employed on street circuits, and if the trouble to trees resulting from their use is caused by the deposition of the products of combustion of the carbons on the foliage, which appears to be the most rational explanation, it is not likely that any serious difficulty to street trees will follow their use if ordinary care is given to the handling of the residue which gathers in the globes.

Injury to Trees from Wires.

The constantly increasing use of electricity for various purposes makes necessary a more extensive use of wires, which has become a great menace to shade trees. The appearance of streets is injured by the increased number of poles and wires, and the legal restrictions as to the height, distance apart, etc., of the wires of the telephone, telegraph, trolley and electric light companies make the problem of maintaining shade trees on the same street with public-service corporations a serious one. Of all the troubles with which tree wardens have to contend, the wire problem is often regarded as the worst. Notwithstanding the strict laws which some States have adopted in regard to injuring shade trees, the agents of some public-service corporations often have little regard for trees or the laws respecting them. Where 40-foot poles must carry the wires of three or four public-service corporations there can be little or no opportunity to preserve the natural symmetry of shade trees, especially when low branching maples and other trees are planted on the same side of the street with the wires. There is less interference from limbs with low than with high tension wires. Trees like the elm, whose branches form acute angles, offer less obstruction to wires than maples; but not all streets, of course, are planted with elms, which may be as well, considering their susceptibility to various pests and unfavorable climatic conditions.

The best solution of the wire problem lies in burying the wires. This has been done to quite an extent in large cities, especially in the business sections, the telephone corporations having adopted this system to a much greater extent than the electric light companies. It is an expensive system, however, and those who so strenuously advocate its adoption do not always consider that in the end it is the patrons who have to pay for it.

Another method of preventing wire injuries is the erection of high poles to bring the wires over the trees. This is sometimes done, especially where the trees are young or of a species that naturally grows low, when a very high pole would be sufficient to clear them for many years. The cable system may be used for telephone wires, and much injury to trees prevented. Large cables are rather expensive to install, but what is termed the "ring construction" system may be used to advantage in many instances, particularly in the suburbs. In this way it is possible to run a line through avenues of fine trees in the country districts without necessitating pruning or disfiguration.

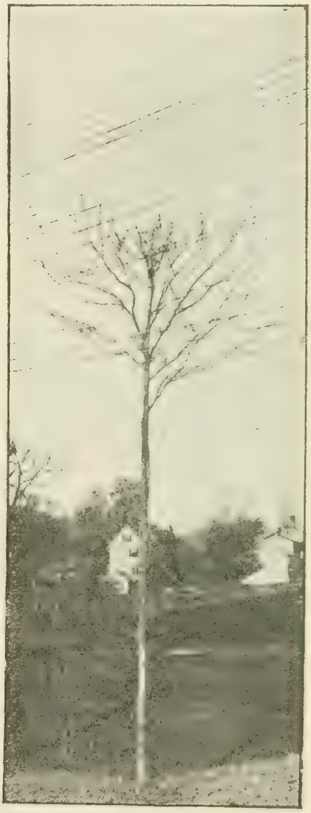

FIG. 103. — Showing the destructive effect on the growth of a maple tree of a mass of wires.

Rights of way for poles on private property back of residences are sometimes secured, and by this means the poles and wires may be removed from the streets, much to the advantage of the trees. But such rights are often difficult to secure, and are not always satisfactory either to the public-service corporations or the owners of the property. The former naturally do not care much for these rights of way unless they are legal and permanent, and the owners in granting permanent rights run a risk of lowering the value of the property. Most of the very high-tension transmission services, however, are at present on private property and seldom interfere with trees. High-tension lines are affected seriously merely by close proximity to trees; therefore, these rights of way have to include broad strips of land, which of course is expensive.

On general principles, it is not wise to allow wires to be attached to trees, although this is often done. Trolley and electric light wires are frequently guyed to trees, but they are a source of danger, since injury is likely to occur from the crossing of the wires, and lightning discharges occasionally pass from the wires to the tree, causing damage. It is, however, often better to allow this than to allow the erection of ugly poles; but proper insulation of the wires should be insisted on, although ordinary insulators have little effect on lightning discharges. The lagbolt system in common use for guying wires to trees is not the best method, for sooner or later the wire and bolt become imbedded in the tree and cause injury. Moreover, a direct metal connection with a tree is objectionable, as has in more than one instance been proved. The block system is better, although it may not in all cases be free from objections. (See Fig. 42.) In no case should a wire be allowed to pass tightly around a tree, as it will girdle it in time. When live wires come into contact with limbs, some type of insulator should be employed similar to that shown in (1), Fig. 105, of which there are various types, some being quite effective in preventing injury from low-voltage lines. The type shown in (2), Fig. 105, is cumbersome and unsightly, but is one of the most effective. The principle of the porcelain and dowel insulator is good, but it has a tendency to slide on the wires and to become displaced. If it were provided with larger dowels, and the danger of displacement on the wires done away with, it would prove much more satisfactory.

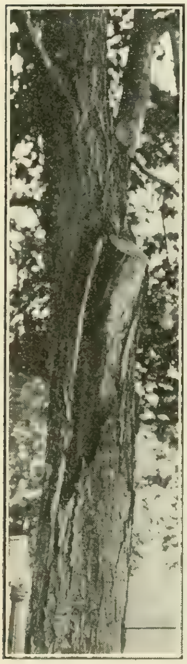

FIG. 104. — Showing maple tree injured by lightning discharge from trolley guy wire, causing death of limb and laceration of trunk.

Wires often accidentally come into contact with trees by the displacement of poles, particularly on curves where the strain is very great, but much of this injury may be prevented by imbedding the poles in Portland cement. It should be pointed out that the necessity for guying poles to trees may be obviated in this way.

Better methods of handling this vexatious question of wires and shade trees should be forthcoming in the future, and even at the present there must be a compromise between the tree warden or city forester and the companies as to the best method of wiring through tree belts and the amount of pruning allowed. Conditions at present favor the corporations, as they are furnishing valuable and necessary facilities for business, and in towns they obtain their franchises and location of poles from the selectmen with little difficulty. The selectmen notify the abutters of any contemplated installations of poles and wires or of changes to occur in the systems, and the abutters are given a hearing. However, they usually wake up to their duty only after the installation of the lines, when the tree warden must assume all responsibility for injury to trees. He has to choose between two courses, — prevent the pruning or permit it. In either case the companies can erect the poles and install the wires, allowing the wires to burn their way through the trees, although this, of course, often causes trouble to the corporation as well as to the abutter. In case of injury to trees the warden has access to the courts, but most companies are willing to put up with a few moderate fines for the sake of the right of way through a tree belt.

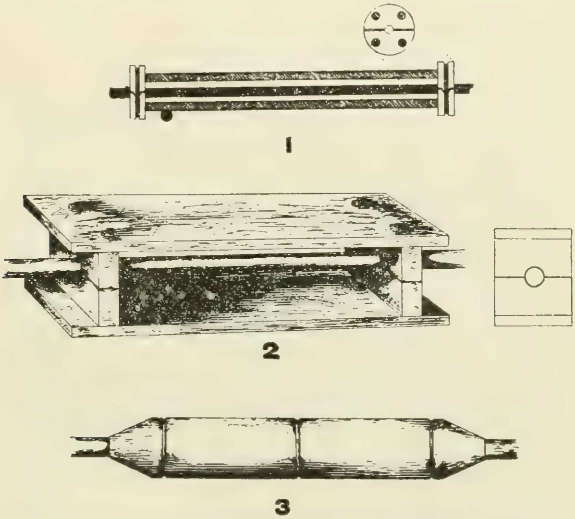

FIG. 105. — **Showing different types of guards for electric wires: 1, porcelain dowel guard; 2, porcelain wood guard; 3, wooden sleeve.**

THE SPRAYING OF SHADE TREES.

The great value and economic importance of spraying shade and fruit trees have resulted in placing on the market a large variety of fungicides and insecticides and types of machinery. Massachusetts has unfortunately been obliged to spend more money in spraying than any other State, and many towns and cities in the eastern part of the State, where the brown-tail and gypsy moths are so prevalent, appropriate thousands of dollars yearly for spraying.

Besides the larger spraying enterprises which are being carried on for the suppression of the gypsy and brown-tail moths, much private work is being done, and hundreds of tons of arsenate of lead are used annually in this work. While the above-named pests have not at present invaded the central and western parts of the State to any extent, other pests necessitate spraying our shade trees.

For years a great deal of attention has been given to the improvement of spraying machines, nozzles, etc. It has often been a question whether our towns or cities can afford to use the methods which are recommended and practiced by the best orchardists for shade trees. The aim of the orchardists is to cover every part of the tree which needs protection with a very fine mist spray. This method cannot be too closely followed by orchardists, since it is not necessarily expensive when only orchard trees and small fruits and crops, such as potatoes, are concerned. However when we have to spray large elms, the question becomes an entirely different one.

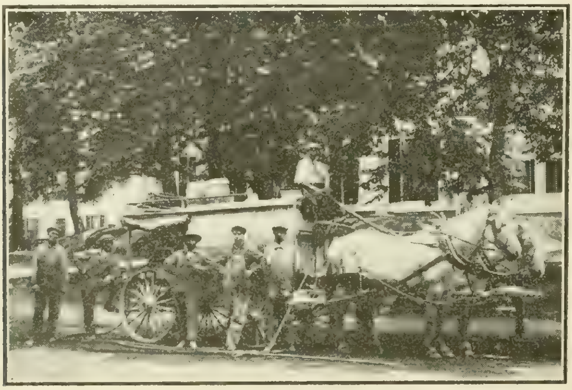

FIG. 106. — Large spraying equipment.

A few years ago some large elms located in the public square in one of our cities were sprayed by the same methods used by the best orchardists, at an expense of something like $16 per tree. These trees, to be sure, were unusually large, but the cost was so great that in our opinion it set a limit to the amount of spraying which should be undertaken by such methods. Most of the former spraying of shade trees was done by this very expensive method at a cost of $1.50 upwards for trees 14 to 18 inches in diameter. In much of this early spraying the Vermorel, Ware or similar fine-spray nozzles on poles were used, and spraying had to be done at close range for the best results. The early gypsy moth work was done in this same way, any other method at that time being considered useless. This method entailed a great deal of climbing on the part of the sprayers, and was a slow and costly process. With the improvement of gasoline engines, pumps, etc., together with the utilization of coarse nozzles, more efficient methods came into vogue. Some years ago the Gypsy Moth Commission abandoned these fine nozzles and close-range methods of spraying, and at the present time use is made only of wide aperture nozzles and solid streams, with large hose. Exceptionally high pressure is obtained from powerful machine sprayers. With the larger area which has to be treated at the present day the older method would prove prohibitory, not only on account of the expense, but also because of the time involved. Virtually all the spraying with these large modern machines is done from the ground, doing away with the necessity for ladders and for climbing trees; and by using one or more lengths of hose large areas may be treated from one spot. This method of spraying trees is very effective and very much cheaper, the average cost of spraying woodlands being something like $6 or less per acre. With this method the spraying mixture is delivered to the nozzle through a large strong hose 1 inch in diameter, under a pressure of 200 to 275 pounds, the high pressure breaking the spray up into a fine mist. The spray has considerable spread when broken up, which is a desirable feature in treating woodlands and country roadsides, but on this account it is more or less objectionable for use on residential streets in cities and towns, as it is likely to disfigure anything it touches. The high-pressure, solid-stream equipments are the cheapest, and are more practical for shade tree work than anything that has as yet been devised.

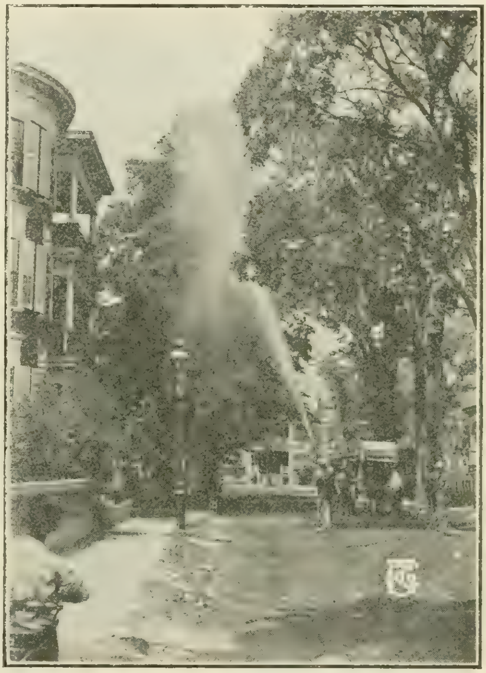

FIG. 107. — Spraying from the ground with solid stream and high pressure (Worthley nozzle).

What might be termed a compromise between the fine-nozzle system and the high-pressure, coarse-nozzle or solid-stream system employed in the gypsy moth work is often used in spraying shade trees at the present day. This consists in the use of the Bordeaux nozzle, which has an aperture of about three thirty-seconds of an inch. When used on a hand pump with a pressure of from 50 to 70 pounds, or even more, it does not give, in our estimation, a satisfactory spray because it is not broken up sufficiently. When a small number of trees is to be sprayed and an expensive equipment cannot be afforded, small hand pumps will do the work, but when it becomes necessary to spray 500 or 1,000 trees in the course of a few weeks, power sprayers are necessary and more economical.

The Bordeaux nozzle has the advantage of being adjustable and can be used either as a mist nozzle or at more or less long distance. As a long-distance nozzle, however, under any pressure, it is unsatisfactory and much inferior to other long-distance sprays. Moreover, with the use of the Bordeaux nozzle it becomes necessary to use a ladder and to do some climbing. The aperture is so small that with any pressure the stream is limited in its height.

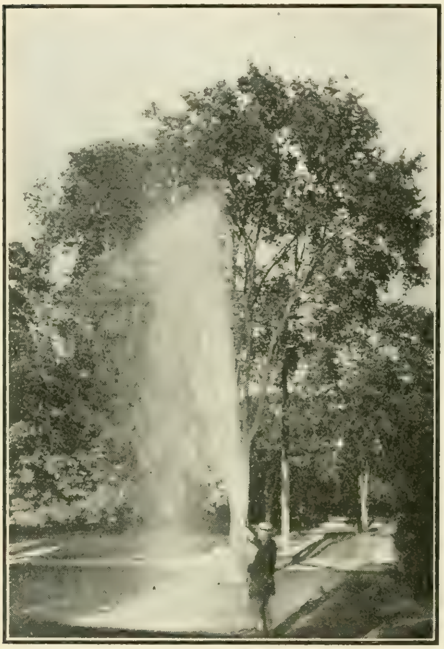

FIG. 108.—"M. A. C." nozzle spray with high-pressure and atomizing point intercepting the stream.

The most important factors necessary for economical work in spraying shade trees on a large scale are machines powerful enough to maintain a constantly high pressure, an efficient nozzle, and competent men to do the work. By high pressure we mean a pressure of 200 to 250 pounds, preferably the latter. This should be maintained constantly, and the capacity should be sufficient to maintain this pressure in a 1-inch delivery hose, if necessary, provided with a nozzle with an aperture one-quarter inch or more in size. With the mist nozzles, or even with the Bordeaux nozzle, a pressure of over 150 pounds is useless and unnecessary. With this pressure, or even less, depending on the nature of the nozzle employed, the maximum results may be obtained. It is extremely important for the best work in spraying that there should be as little friction as possible. Therefore, care should be exercised to have no reducing valves or couplings anywhere on the line to reduce the volume, since it is essential to have an uninterrupted flow of the spraying mixture directly to the nozzle. In this respect the fixtures usually found on the market are poorly adapted to good work, and are often useless, with the exception of those used by the State in spraying for the gypsy moth. These are excellent.

Too much attention cannot be given to the nozzle. It should be adapted to the work required of it, and a satisfactory or ideal nozzle is worth almost any price. It should be constructed on mechanical principles which will enable it to break up the spraying mixture into as fine a mist as possible, and to do this at a distance convenient for the economical spraying of trees. The ideal nozzle for spraying either from the ground or from a ladder should possess some carrying features, and still break up the spray finely. The nozzle should not be encumbered, any more than the hose, with worthless mechanical devices which produce friction without adding anything to its efficiency, and for this reason we believe that it is better to employ mechanical devices to break up the spray after it has left the nozzle rather than in the nozzle itself. This applies, of course, to that type of nozzle intended to be used with high pressure, either from the ground or from a ladder, since in this case it is necessary to have nozzles adapted to throw a certain distance in order to reach the foliage, and have it broken up into as fine a mist as possible. This does not apply to types of nozzles like the Vermorel and Friend, which are well adapted to the purposes for which they are intended.

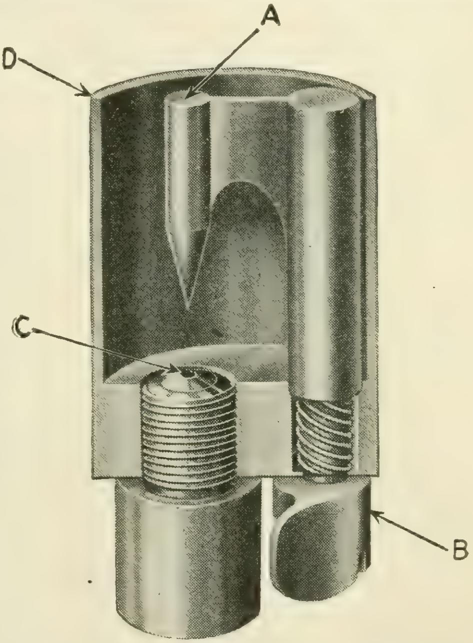

Fig. 109. — "M. A. C." nozzle. A, atomizing point or deflector; B, wing handle to adjust or swing point; C, nozzle proper; D, hollow case to protect A and C.

For high-pressure, solid-stream spraying in long-distance work, the Worthley tips are best. These tips range in size from one-eighth inch upwards, according to height of stream desired. They are constructed so as to break the stream into a mist at a certain height. With this type of nozzle the tops of trees can be sprayed most effectively, although the lower foliage does not receive so much of the spray. To overcome this difficulty the writer has devoted a great deal of time to experimenting with new types of nozzles, and from some forty or more designs two have been constructed which have given good results. One of these, known as the "M. A. C. nozzle,"[1] has been patented and placed on the market. This nozzle is adapted for use with apertures ranging from one-eighth inch upwards, and is adjustable so that different types of sprays may be produced. It is designed for high-pressure work, and is more efficient at relatively close range than long distance; consequently, when used in connection with the Worthley tips an effective method of spraying results. With a three and one-half to six horse-power machine it can be used with one-eighth to three-sixteenths inch tips effectively, but in such cases a ladder must be employed with high trees.

The securing of competent men is also important in spraying. Any reliable man of common sense can learn to spray in a short time, and there should be little difficulty in securing such men if they are treated properly and well paid.

At the present time there are numerous types of spraying machines on the market ranging from two horse power on, and costing from $200 to $1,200. When it becomes necessary to spray a large number of trees in towns or cities, only the large size machine should be used, but the large machines are rather costly for small towns with a limited amount of work to be done.

In the case of towns having a limited amount of work to be done, it is better either to contract the work or secure a five or six horse-power machine. As a rule, contract spraying of shade trees, done with small hand pumps or with small machines, is quite unsatisfactory, the equipment not being adapted to the best work at the usual contract prices, especially when many large trees must be sprayed. The cost of spraying large trees with hand pumps or small machines with the Bordeaux nozzle should be at least $1.50 per tree, and few contractors take work at this price. When contracts are accepted at the price of 70 cents per tree the work must be slighted with the inferior equipment employed, and even then it is done at a loss. With the use of large machines and solid-stream sprays, city trees have been sprayed for about 20 cents each, and an average price in cities and towns would be from 20 to 39 cents. In one instance the average price for spraying about 900 elm trees, with an average diameter of 20 inches, during a period of six years was 57 cents per tree; a three and one-half horse-power engine and an "M. A. C. nozzle" were employed. Use was made of a ladder, but very little climbing was done, and the price represents the bare cost of material and labor. Deterioration of machinery, repairs, etc., are excluded. An outside contractor should of course receive considerably more for spraying to offset the extra items of expense, such as the cost of transportation, housing his men, etc.

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[1] This nozzle was devised by the writer, and the patents are held by the Massachusetts Agricultural Experiment Station. It is manufactured and sold by Brackett, Shaw & Lunt, 62 North Washington Street, Boston, Mass.

Valuation of Shade Trees.

The valuation of shade trees is a very important question, and opinions on the subject often differ greatly. There are several different ways of arriving at the value of a shade tree, but in all of them the many factors modifying the value of a tree must be taken into consideration.

Since a tree planted for its shade, ornamental purposes, etc., possesses a utilitarian or property value, its real worth is usually represented by the cost of duplication. The amount of reduction in value of property from the loss of a tree is simply equivalent to the value of the tree, which in turn is represented by the amount it would cost to duplicate it. There is a limit to the size of tree that can successfully be transplanted, but it is possible to duplicate an 18-inch tree, and the value of trees that are too large to transplant may be estimated proportionately.

The transplanting of large trees is thoroughly practicable when done by men who understand it. A tree 6 inches in diameter may be moved for from $6 to $20, and one 14 inches in diameter for from $30 to $80, depending upon the availability of transplanting apparatus and of suitable trees.

Another method of determining the value of a tree, mentioned briefly above and often used in court, is to determine the decrease in value of the real estate affected by the loss of the tree, and expert appraisers of property are usually called in when this method is used.[1]

This method has its limitations, for real estate men are not necessarily familiar with all the factors affecting the value of a tree, — diseases, expectation of life, etc., which must be taken into consideration; consequently, they often set the value too high or too low. Moreover, the price per foot of real estate has little or nothing to do with the real value of a tree, which may be worth as much on a piece of property valued at $2,000 as on one valued at $6,000. As a matter of fact, the trees located on real estate have very little effect on the price obtained for the property, this depending much more upon the ability of the salesman. Then, too, while trees, shrubbery and other ornamental planting undoubtedly add value to property, it is a question whether the buyer often very seriously considers this fact when it comes to actually paying over his money. A tree is likely to be destroyed at any time by wind storms, lightning, etc., in which case it is impossible to recover damages, and it therefore does not appeal to the average buyer as a substantial property asset. Trees may be insured, but the writer's experience is that comparatively few persons regard trees as of sufficient value to warrant much expenditure. This is substantiated by the fact that in only a few cases, where trees have been destroyed by public-service corporations, and damages paid for them, have we observed any attempt to replace the dead trees with others of large size, and seldom even with small ones. Not infrequently the destruction of a tree is considered in the light of a blessing, although damages are always insisted on. It is almost invariably true that real estate owners who allow horses to disfigure their trees year after year, not showing enough interest to expend 75 cents or so for wire protection, usually insist on the heaviest damages when these same trees are destroyed by public-service corporations.

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[1] Many trees attain to a diameter of at least 18 inches, and in many cases even more, in fifty years. Assuming that it costs $2 to plant a tree, and that it is worth $150 at this age and size when in good condition, the return on the original investment would be 9 per cent., compound interest.

Another method of estimating the value of trees is by obtaining the cross-section area. Cross-section areas of trees are often obtained at a certain distance from the ground and the value computed at so much per square inch. The æsthetic features, location, species, imperfections, etc., are also taken into consideration in determining the value of the tree. This method may be used in deciding the value of trees too large to transplant, but even here some allowance should be made, since their utility, shade value, etc., do not increase proportionately with their increase in size.

There are many factors underlying the valuation of trees which should be, but seldom are, taken into consideration, and a short discussion of these follows: —

A tree may be valuable in more than one way. It may possess a *species* or *varietal* value, *i.e.*, it may be of a type possessing horticultural value for propagating purposes; it may possess *historic* value, such as the Washington elm and others; it may have merely a *sentimental* value, in being associated with some family event; or it may possess *æsthetic* value, from its landscape effect and intrinsic beauty; again, it may possess only a *timber* value, which in most cases is insignificant; and finally, it has a *utilitarian* or *property* value, which naturally includes many factors.

Other features which help to determine the value of a tree are as follows: —

Size. — Size is of importance in determining the value of a tree.

Form. — A tree may be of good size and of very poor shape. Unfortunately there are many trees which, on account of their poor shape, should never have been planted.

Vigor. — Shown by the rate of growth, size of leaves, color of foliage and condition of bark.

Susceptibility to Various Troubles, to Specific Diseases, etc. — These may follow as a result of the environment or may be peculiar to individuals.

Physical Condition. — Shown by freedom from cavities and wounds, caused by unscientific pruning and other mechanical agencies, — borers, various animals, etc.

Species. — The species is important also, not only from the standpoint of beauty but from its conformity to the environment, its longevity and susceptibility to disease. There are many species which were formerly of much greater value than they are to-day, owing to the increased number of troubles affecting them now, *e.g.*, the elm-leaf beetle, leopard moth, winter injury and drought.

Location. — If the importance of the location of a tree were better realized, much more accurate valuations would be given trees which have been destroyed. For instance, a tree located on a well-planted avenue is worth more than one growing on a poorly planted avenue.

A tree forming part of a symmetrical line of trees is, as a rule, of more value than one of an irregular group.

A tree planted too closely to others is of less value than one which has a chance to grow without restriction.

A tree located in a wide tree belt is worth more than one growing in a narrow tree belt.

A tree growing on a narrow avenue is of less value than one on a wide avenue, for in the latter case the water mains, sewers, etc., may be farther from the roots, which are less likely to become injured.

A tree growing inside the sidewalk is of more value than one growing on the edge of a road near the curbing, or in a ditch. Usually the farther from the roadbed the tree is located, at least in cities, the more valuable it is, for the roots are often amputated close to the trunk in street excavating, sidewalk and curbing construction, etc., and the tree is much more liable to injury from horses and trucks, runaways, etc.

A tree growing in a street where water mains, sewers, underground conduits and gas pipes are so numerous as to necessitate digging up the roadbed cannot have the value of one growing in an undisturbed roadbed.

A tree planted near manufacturing establishments or in other locations where it is subject to an atmosphere of smoke and various gases is also unfavorably located since its expectation of life is reduced.

A tree located where it is likely to become affected by sun scorch or drought is of less value than one growing under more normal conditions. Cultivated soil is better for a tree than a lawn, mowing or pavements, but next to cultivation the lawn conditions are most favorable. Abnormal chemical conditions of the soil and unsuitable soil texture affect growth and development. The location of a tree as regards distance and direction from a residence are important from the shade point of view.

Trees located close to oiled roadbeds are unfavorably situated, since the dust from oiled roads injures foliage. There is also a possibility of the roots themselves being affected by the oil.

On account of variation in their susceptibility to disease and to injury from climatic conditions, trees are often of more value in one location than another; for instance, those growing in country towns are usually under more wholesome conditions than those in cities. They may also be located in situations where certain pests thrive. While trees in cities are relatively short lived, they are considered of more value than town trees, because they serve a larger population.

The nature of the species and the conditions under which a tree is growing help to determine its expectation of life. An elm tree may live for two hundred to three hundred years in some localities, and in others sixty or seventy years is its limit, while the duration of life of other trees is even more restricted.

The extensive cutting of roots, made necessary by modern city street conditions, where business blocks with their deep foundations are often erected within a few feet of the highway trees, and where the placing of sidewalks, curbings and various other modern conveniences necessitate considerable excavating, renders even the most perfect specimen of tree almost worthless in a short time.

Court Decisions concerning Damages to Trees.

Of the many court decisions regarding the injury and death of trees, quite a few are valuable as precedents. It is too often the case that the official representatives of public-service corporations, which hold franchises granted by cities and towns, assume that the corporations have entire jurisdiction over everything interfering in any way with the operation of their systems. As regards this point may be quoted the decision of a justice of the Supreme Court, who stated that public-service corporations "have only such rights as others to the use of streets, and are subject therein at all times to reasonable regulation or even to termination at any time if the supreme authority acting in the public service shall so determine." He further maintains that "they have no rights of property in the streets, and their privileges are merely temporary ones, which may be recalled at any time and which carry with them no right of property whatever."

From a lack of understanding of or inability to conform to the law, and a disregard of the rights of the people, this often leads to friction between those having special care of trees and representatives of the corporations. The heads of corporations have always been better disposed toward public utilities than their representatives, and some of them have laid down stringent rules in regard to shade trees which their representatives are supposed to follow. Most States, however, recognize that trees located on public highways enhance the value of the abutter's property, and in case of the destruction of or injury to such trees, the abutter has the right to claim damages.

In a case decided by the Appellate Division, New York, an owner of land abutting on a city street, whose ownership did not extend to the middle of the street but "who had set out ornamental shade trees on the sidewalk in front of his premises at his own expense and with the sanction of the municipal authorities, is entitled to have such trees protected against negligent or willful destruction at the hands of third parties. He has a right in such trees in the nature of an equitable easement, and when one is girdled and destroyed by a horse, may recover from the owner of the horse the damages thus sustained."

In Minnesota an injunction was granted by the judge to restrain the defendant from cutting, mutilating or in any way damaging trees whose limbs were threatened by an old house that was being moved through the streets. Along the route which the building must take in the course of moving were several shade trees which would have to be destroyed in order to move the building. The court maintained that "there can be no question of the right of plaintiff to the protection of the court to save these valuable trees from mutilation and possible destruction. The fact that these trees are in the street and not within the boundary line of plaintiff's premises does not alter in the least his right to have them protected, as they are his property. In the absence of proof to the contrary he is the owner of the land in front of his premises to the center of the street, subject only to an easement in the public to use it for the purposes of travel and the usual and ordinary incidents thereof. His rights of ownership yield only to the public welfare and convenience, and to the power of the municipal authorities to appropriately adapt the street and maintain it to meet the necessities of the travelling public."

From various court decisions it would appear that the value assigned to trees has sometimes been too high and often too low, and in the main, the extent of the damages resulting from the destruction of trees is based upon the deterioration occurring to the adjacent property. In general, it may be stated that a tree 18 or 20 inches in diameter, in good condition and in a desirable location, is worth $150, and a smaller one is of corresponding value. In private settlements, which are often made, for trees injured by public-service corporations, amounts ranging from $15 to $150 have been paid for trees of the above size, but in many cases from $40 to $100 is considered sufficient compensation for trees ranging from 10 to 18 inches in diameter, depending entirely, of course, upon the many factors that influence the value of a tree.

Several typical cases of court decisions concerning damages to trees follow: —

The jury of a circuit court in Missouri once awarded $200 against a telephone company for cutting out the top of a shade tree without consulting the owner. The tree in question was a 6-inch poplar which interfered with the telephone wires, and the workmen, without consulting the abutter, chopped out the top and center of the tree. The abutter sued for $300 and received $200.

A similar instance occurred in North Carolina, when an electric lighting company was sued for damages for cutting a tree on the edge of a sidewalk, even after being provided with the permission of the superintendent of streets, approved by the board of aldermen. The jury awarded the plaintiff a verdict of $499. Of course the case was appealed, but the judgment of the State Supreme Court was that while the city had the power under its charter to control streets and sidewalks and to remove obstructions when necessary, it did not, when it condemned land for highway purposes, acquire a title to it but merely a right of way over it, so that the plaintiff was still the owner of the tree.

In another case a resident of New York, owning residential property abutting on the city street, brought suit against a gas company for the destruction of trees by gas. The case involved the destruction of some maple trees thirty-five years old, all in a thriving condition and furnishing good shade. Four of these trees were destroyed by the negligence of the gas company in permitting gas to escape from its pipes into the soil about the roots of the tree. Action was brought to recover the damages alleged to have been sustained by the plaintiff by reason of these facts, and the jury found a verdict in his favor for the sum of $150. Upon appeal to the Appellate Division, the judgment entered upon the verdict was unanimously confirmed. The court held, as a matter of law, that the plaintiff had a property right in these trees, although they were not planted upon lands to which he had a title.

The question of negligence in the destruction of shade trees is an important one, and opinions seem to differ as to what constitutes negligence. There are some cases in which negligence has not been established and decisions were rendered in favor of the defendants, although it should be pointed out that an appeal to the higher court often reversed such decisions. The case of Robbins *v.* the Hartford Gas Company, pertaining to the destruction by gas of shade trees located on the highway and on private property, resulted in a decision for the defendant, but on appeal to the higher courts the defendant made a satisfactory settlement with the plaintiff. In the case of Rooney *v.* the Hyde Park Gas Company, which involved a number of shade trees on the highway and on private property which were supposed to have been injured by gas, a decision was given in favor of the defendant. The gas leak as admitted by defendant occurred some distance away from the trees, and it was not established that they had been injured by gas, neither could negligence be established.

These cases concern action brought by property owners against public-service corporations for the destruction of trees, but in accordance with our Massachusetts statutes city foresters or tree wardens can bring action for injury or destruction to shade trees located on the public highway. For instance, the city forester of Springfield brought suit against the Springfield Gas Company for the destruction of sixty shade trees, and the judge rendered a verdict in favor of the defendant, since negligence was not established. The gas company, however, made no attempt to establish any case; moreover, they had previously settled with the owners of the adjacent property for many of the trees involved, thereby acknowledging in such settlement that the trees had been killed by gas.

In another case the town of Athol brought suit through the tree warden against the Athol Gas Company for killing public shade trees by gas. The decision given by the judge of the local court was in favor of the plaintiff. The gas company appealed, but again lost its case before a jury in the higher court. In the case of the Superintendent of Parks, Lowell, *v.* the Lowell Gas Company, in which some fifty trees were supposedly killed by gas, a fine of $900 was imposed on the company in the police court, the same being paid to the city treasurer. In addition to the fine, the gas company settled with many of the abutters.

A few years ago fifteen tupelo trees were cut on private land by an electric railway company. The court awarded triple damages on the ground that the cutting was willful, and the company was fined $1,200.

A case is recorded of a superintendent of an electric light company being adjudged guilty in a Massachusetts court on a charge of injuring and destroying shade trees on the highway. The court imposed a fine of $25. In another case a lineman was fined $15 in the district court on complaint of a tree warden for climbing trees with spurs.

Innumerable other court cases could be cited similar to those already given illustrating the laws in regard to public shade trees. In some States, however, according to decisions of the courts, public shade trees may be destroyed from almost any cause without any compensation to the adjacent property owner. By far the larger number of cases of injury to and destruction of shade trees from various causes never reach the courts, and it is much better to arrive at some satisfactory settlement by arbitration than to resort to criminal proceedings. One Massachusetts city, however, has attempted to require a public-service corporation to give a bond for the payment of damages to trees, but this regulation was not adopted by the aldermen of the city.

There are only a few instances, to my knowledge, of the courts awarding damages for trees supposed to be killed by electricity. Most courts would undoubtedly allow damages for serious burnings brought about by wires, but there are only a small number of cases in which electricity has actually killed a tree and in these cases the death of the tree was due to a reversed polarity in the electric railways.[1]

Codified Shade Tree Laws of Massachusetts, 1915.

For several years prior to 1899 there was a provision in the Massachusetts statutes that towns might elect tree wardens. By the acts of that year it was provided that every town must elect a tree warden, and the duties and powers of the office were defined. The tree warden law of 1899, with certain amendments in details, remains in force to-day and regulates the care of shade trees in every town in the Commonwealth.

Chapter 145, General Acts of 1915.

Section 1. The powers and duties conferred and imposed upon tree wardens in towns by this act are hereby conferred and imposed upon the officials now or hereafter charged with the care of shade trees within the limits of the highway in cities, by the charters of the said cities, by other legislative enactments, or by the ordinances of the said cities, and upon such officials as the city governments shall designate to have charge of said shade trees where it is within their power to transfer such duties, by ordinance or otherwise.

Section 2. The tree warden may appoint and remove deputy tree wardens. He and they shall receive such compensation as the town determines or, in default thereof, as the selectmen allow. He shall have the care and control of all public shade trees, shrubs and growths in the town, except those within the limits of a state highway, and except those in public parks or open places under the jurisdiction of the park commissioners, and of those, if so requested in writing by the park commissioners, and shall enforce all the provisions of law for the preservation of such trees, shrubs and growths. He shall expend all money appropriated for the setting out and maintenance of such trees, shrubs and growths, but no trees shall be planted within the limits of a public way without the approval of the tree warden; and in towns until a location therefor has been obtained from the selectmen or road commissioners, where authority has been vested in said commissioners. Regulations, other than those made by the terms of this act, for the care and preservation of public shade trees made by him, and in towns approved by the selectmen, and posted in two or more public places, imposing fines and forfeitures of not more than twenty dollars in any one case, shall have the force and effect of town by-laws. All trees within or on the limits of a public way shall be public shade trees; and when it appears in any proceeding where the ownership of or rights in the tree are material to the issue, that, from length of time or otherwise, the boundaries of the highway cannot be made certain by the records or by monuments, and that for that reason it is doubtful whether the tree be within or without the limits of the highway, or is public or private property, it shall be taken to be within the limits of the highway and to be public property until the contrary is shown.

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[1] Electrical Injuries to Trees, Mass. Agr. Exp. Sta. Bul. 156, 1914.

SECTION 3. Except as provided by section five, public shade trees shall not be cut, trimmed or removed, in whole or in part, by any person other than the tree warden or his deputy, whether such person is or is not the owner of the fee in the land on which such tree is situated, except upon a permit in writing from said tree warden, nor shall they be cut down or removed by the tree warden or his deputy or other person without a public hearing at a suitable time and place, after notice thereof posted in two or more public places in the town or city and upon the tree at least seven days before such hearing, and after authority granted by the tree warden therefor: *provided, however*, that if the tree warden shall refuse to cut or remove or issue a permit to any such owner to cut or remove any such tree or other growth, the damages, if any, sustained by him shall be determined in towns by the selectmen and in cities by the officer or officers in charge of the public shade trees and shall be paid by the town or city. Any person aggrieved by the action of the selectmen or said officer or officers in charge of the public shade trees as to the trimming, cutting, removal or retention of any such tree, or as to the amount awarded to him for the same may have the damages, if any, which he has sustained, determined by the superior court for the county in which the said tree is or was situated, upon a petition filed for the purpose, in the same manner as for the taking of land for ways; and his damages, so determined, shall be paid by the town or city,

SECTION 4. Tree wardens shall not cut down or remove or grant a permit for the cutting down or removal of a public shade tree if, at or before a public hearing as provided in the preceding section, objection in writing is made by one or more persons, unless such cutting or removal or permit to cut or remove is approved by the selectmen or by the mayor.

SECTION 5. Tree wardens and their deputies, but no other person, may, without a hearing, trim, cut down or remove trees, under one and one half inches in diameter one foot from the ground, and bushes, standing in highways; and, if ordered by the mayor and aldermen, selectmen, road commissioners or highway surveyor, shall trim or cut down trees and bushes, if the same shall be deemed to obstruct, endanger, hinder, or incommode persons travelling thereon. Nothing contained in this act shall prevent the trimming, cutting or removal of any tree which endangers persons travelling on a highway, nor the removal of any tree, if so ordered by the proper officials, for the purpose of widening the highway, and nothing herein contained shall interfere with gypsy and brown tail moth suppression, as carried on under the direction of the state forester and the United States department of agriculture, except the cutting and removal of trees, shrubs and growths that are one and one half inches or more in diameter one foot from the ground.

Section 6. Whoever violates any of the provisions of the preceding sections of this act shall forfeit not more than five hundred dollars to the use of the town or city.

Section 7. Towns and cities may appropriate money to be expended by the tree warden in planting shade trees in the public ways, or, if he deems it expedient, upon adjoining land, at a distance not exceeding twenty feet from said public ways for the purpose of improving, protecting, shading or ornamenting the same: *provided, however*, that the written consent of the owner of such adjoining land shall first be obtained.

Section 8. The Massachusetts highway commission shall have the care and control of all trees, shrubs and growths within the limits of state highways, and may trim, cut or remove such trees, shrubs and growths, or license the trimming, cutting or removal thereof. No such tree, shrub or other growth shall be trimmed, cut or removed by any person other than an agent or employee of the commission, whether such person is or is not the owner of the fee in the land on which such tree, shrub or growth is situated, except upon a permit in writing from said commission: *provided, however*, that if the commission shall refuse to issue a permit to any such owner to cut or remove any such tree, shrub, or other growth, the damages, if any, sustained by him shall be determined by said commission and paid by the commonwealth. Any person aggrieved by the action of the commission as to the trimming, cutting, removal or retention of any such tree, shrub or other growth, or as to the amount awarded to him for the same by the commission, may have the damages, if any, which he has sustained, determined by the superior court for the county in which the said tree, shrub or other growth is or was situated, upon a petition filed for the purpose, in the same manner as for the taking of land for highways, and his damages, so determined, shall be paid by the commonwealth.

Section 9. Whoever affixes to a tree in a public way or place a play bill, picture, announcement, notice, sign, advertisement or other thing, whether in writing or otherwise, or cuts, paints or marks such tree, except for the purpose of protecting it or the public and under a written permit from the officer having the charge of such trees in a city or from the tree warden in a town, or from the Massachusetts highway commission in the case of a state highway, shall be punished by a fine of not more than fifty dollars for each offence. Tree wardens shall enforce the provisions of this section: *provided, however*, that in case of the failure of a tree warden to act in the case of a state highway within thirty days after the receipt by him of a complaint in writing from the Massachusetts highway commission, said commission may proceed to enforce the provisions of this section.

Section 10. Whoever without authority trims, cuts down or removes a tree, shrub or growth, within the limits of a state highway or maliciously injures, defaces or destroys any such tree, shrub or growth shall be punished by imprisonment for not more than six months or by a fine of not more than five hundred dollars, to the use of the commonwealth.

Section 11. Whoever, wilfully, maliciously, or wantonly cuts, destroys or injures a tree, shrub or growth, which is not his own, standing for any useful purpose, shall be punished by imprisonment for not more than six months or by a fine of not more than five hundred dollars.

Section 12. Whoever wantonly injures, defaces, or destroys a shrub, plant or tree, or fixture of ornament or utility, in a public way or place or in any inclosure, or negligently or wilfully suffers an animal driven by or for him or belonging to him to injure, deface or destroy, such shrub, plant, tree or fixture, or whoever by any other means negligently or wilfully injures, defaces, or destroys such shrub, plant or tree, or fixture, shall forfeit not more than five hundred dollars, one half to the use of the complainant and one half to the use of the city or town in which the act was committed; and shall in addition thereto be liable to said city or town or other person interested in said tree for all damages caused by such act.

SECTION 13. Section fifteen of chapter twenty-five of the Revised Laws, in so far as it relates to trees; section ten of chapter fifty-one of the Revised Laws, in so far as it gives authority over trees and bushes; sections one hundred and one, one hundred and two and one hundred and four of chapter two hundred and eight of the Revised Laws, as amended by sections thirty-one and thirty-two of chapter five hundred and forty-four of the acts of the year nineteen hundred and two; section twelve of chapter fifty-three of the Revised Laws, as amended by section two of chapter two hundred and ninety-six of the acts of the year nineteen hundred and eight and by chapter three hundred and twenty-one of the acts of the year nineteen hundred and ten; section thirteen of chapter fifty-three of the Revised Laws, as amended by section three of chapter two hundred and ninety-six of the acts of the year nineteen hundred and eight; section sixteen of chapter twenty-five of the Revised Laws; section one of chapter three hundred and sixty-three of the acts of the year nineteen hundred and ten; and chapter two hundred and seventy-nine of the acts of the year nineteen hundred and five, as amended by chapter two hundred and ninety-seven of the acts of the year nineteen hundred and eight, are hereby repealed.

SECTION 14. The provisions of this act, so far as they are the same as those of existing statutes, shall be construed as continuations thereof and not as new enactments.

SECTION 15. This act shall take effect upon its passage. [*Approved April 7 1915.*

R. L., CHAPTER 208, SECTION 115.

LAW REGARDING THE POSTING OF NOTICES, ETC., WITHIN THE LIMITS OF THE HIGHWAY.

Whoever paints, or puts upon, or in any manner affixes to, any fence, structure, pole, rock or other object which is the property of another, whether within or without the limits of the highway, any words, device, trade mark, advertisement or notice which is not required by law to be posted thereon, without first obtaining the written consent of the owner or tenant of such property, shall, upon complaint of such owner, or of his tenant, or of any municipal or public officer, be punished by a fine of not more than ten dollars. Any word, device, trade mark, advertisement or notice which has been painted, put up or affixed within the limits of a highway in violation of the provisions of this section shall be considered a public nuisance, and may be forthwith removed or obliterated and abated by any person.